

Thesis/
Reports
Nuffer,
S.S.

A STUDY TO REDUCE THE EFFECTS OF THE COTTONWOOD LANDFLOW

JANUARY 1977





18 January 1977

B10363.A0

U.S. Department of Agriculture
Forest Service
Intermountain Region
324 - 25th Street
Ogden, Utah 34401

Attention: Mr. John K. Campbell
Contracting Officer

Gentlemen:

Subject: A Study to Reduce the Effects of the Cottonwood
Landflow

We are pleased to submit the attached report summarizing our investigation and analysis of the Cottonwood landflow. The purpose of the study was to identify the effects of the landflow, evaluate alternative corrective measures and recommend a course of action.

The study consisted of four phases of work.

- a field investigation and review of all available data
- a feasibility study of the alternatives
- an engineering analysis and environmental assessment of the feasible alternatives
- an economic analysis

Of the nine alternatives originally proposed, the following six were considered as feasible solutions:

	<u>Estimated Annual Equivalent Cost</u>
■ Pipeline bypass around the toe	\$ 98,700
■ Debris dam on Manti Creek	118,800
■ Stabilize the Manti Creek Channel	167,200
■ Divert Cottonwood Creek	22,400
■ Do Nothing	16,000
■ Polymer Treatment	91,200

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We have recommended Do Nothing, i.e., no corrective action be taken to mitigate the effects of the Cottonwood landflow.

We have enjoyed the opportunity working with you on this interesting project.

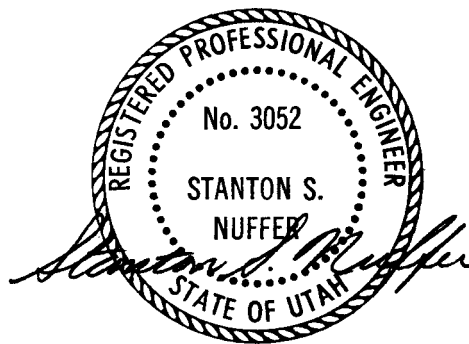
Sincerely,

A handwritten signature in cursive script that reads "Stanton S. Nuffer". The signature is written in dark ink and is positioned above the printed name and title.

Stanton S. Nuffer
Project Director

js
Attachment

A STUDY TO REDUCE THE EFFECTS
OF THE
COTTONWOOD LANDFLOW



CH2M HILL
Engineers - Planners - Economists
January 1977

Project No.: B10363.A0

ACKNOWLEDGEMENTS

During the course of this study, various aspects of the landflow and its effects were discussed with Messrs. Cliff Miller, Forest Engineer; Eugene Hansen, Materials Engineer; and Earl Olson, Geologist with the U.S. Forest Service Intermountain Region, Ogden, Utah. Messrs. Dick Allred, Sanpete District Ranger - U.S. Forest Service; Frank Wanlass, Mayor - City of Manti; and Ned Madsen, President - Manti Irrigation District also provided valuable assistance. Appreciation is extended to these individuals for their cooperation and assistance.

Appreciation is also extended to consultants Richard Craven, James Buell and Michael Treshow; and to Ken Tuttle and Don Andriano of Utah Department of Wildlife Resources who aided in the environmental assessment portions of this study.

SUMMARY

In 1974 and 1975 a large landslide occurred in Manti Canyon; the slide, "Cottonwood landflow," is located in the Manti-LaSal National Forest. The slide is about 1.9 miles long and 300 to 2400 feet wide extending into Manti Creek and partially filling it.

The landflow has caused increased sediment levels in Manti Creek. This increased sedimentation has caused some problems, principally for lands irrigated with Manti Creek water and for the irrigation system itself.

There was also concern that continued movement of the Cottonwood landflow might dam Manti Creek and this landslide-caused dam would overtop, fail suddenly and result in a damaging flood in the City of Manti.

The objectives of this study were to evaluate nine different alternatives to reduce these two effects, increased sedimentation and flood potential, caused by the Cottonwood landflow and to recommend a course of action.

TASKS PERFORMED DURING THIS STUDY

The tasks performed to meet the study objectives were:

1. Field reconnaissance of:

- The Cottonwood landflow and general aspects of Manti Canyon.

- Manti Creek and its aquatic life.
 - Plant and animal communities in the area of the slide and areas in which corrective measures might be taken.
 - Community utilities and facilities affected by Cottonwood landflow.
2. Discussions with representatives of government agencies and residents of Manti.
 3. Reviews of available data and reports by others relating to the Cottonwood landflow and its effects.
 4. Evaluation of alternative measures, to reduce the effects of the slide, considering engineering, environmental, and cost factors.
 5. Preparation of conceptual designs and cost estimates for the most promising alternative measures.

BACKGROUND INFORMATION

Numerous landslides have occurred in Manti Canyon; the Cottonwood landflow is the most recent. Older landslides predate the settlement of the City of Manti and may be on the order of hundreds to thousands of years old.

Sediment concentrations in Manti Creek are not new; the City of Manti itself is built on an alluvial fan of materials carried by Manti Creek and deposited at the canyon mouth. Manti Canyon was created by erosion and landslides bringing

materials to Manti Creek which carried them on to the Sanpete Valley. Therefore, the Cottonwood landflow is part of the natural geologic processes which have created the present day canyon and will continue to shape the land.

Movement of Cottonwood Landflow

Some slow movement of the Cottonwood landflow probably occurred before 1974 as indicated by the need to add nine feet of pipe to the Manti City waterline in the area of the landflow. In June 1974 a rockfall and mudflow at the head or upper end of the Cottonwood landflow occurred which may have triggered the landflow by disrupting surface drainage. Shortly after the rockfall, the upper area began to move. By July 1975 the landflow was fully developed from this head to the toe at Manti Creek. Movements of up to 500 feet occurred. The toe filled in portions of Manti Creek to a maximum depth of about 100 feet. By 1976 movement had nearly ceased; movement at the toe was generally less than 1-foot and the upper area moved only about 5 feet from May to August 1976.

Based on this area's history of movement and the general behavior of landslides, it is likely that large, rapid movements may have ceased. The Cottonwood landflow may have achieved a more stable position similar to that which has occurred in the other, older slides in the canyon. Generally, motion should gradually decrease over a period of time. Movements greater than a gradual downhill creeping may possibly occur again following heavy rain and/or snowmelt but the magnitude of such movements would probably be on a smaller scale than those observed in 1974 and 1975.

SEDIMENTATION

Sediment concentrations in Manti Creek were reportedly much above normal in Fall 1975, after the landflow partially filled the Manti Creek channel and in Spring 1976, the first time high streamflows passed the toe of the landslide.

The amount of sediment carried by the stream should decrease with time to pre-slide conditions as Manti Creek approaches a new equilibrium (if the toe of the landslide does not move further). Indications are that the sediment load is decreasing rapidly, supported by analysis of the 1976 sedimentation data collected by Utah State University. On the west side of the toe, the creek is rapidly armoring itself as the water washes away fine material and leaves gravel, cobbles and large boulders forming a natural riprap protection for the stream bed.

Sediment was deposited in irrigation laterals which then required cleaning. Furrows were lined with sediment reducing the infiltration of irrigation water. This sediment was mostly clay. It appears that the sediment did not cause a large problem nor any significant damage.

Damming and Flooding

The possibility of damming and subsequent flooding caused by landslide movement appears to be a highly unlikely event in that:

- Large motions of the Cottonwood landflow may have stopped.
- Based on the rates of previous movements, there is probably time to take corrective action if a dam begins to form.

- Based on previous movements, if a dam forms it will be very wide and not likely to erode or fail rapidly.
- Because the landslide debris contains a wide range of particle sizes, including large boulders, an overtopped dam would effectively resist erosion and would be unlikely to fail rapidly.
- The maximum reservoir size such a dam could create is comparatively small (about 130 acre-feet). Because the damming and flooding potential is considered very unlikely, damming and flooding were eliminated as criteria in evaluating the various alternatives.

ALTERNATIVE COURSES OF ACTION

Nine alternatives were evaluated, six in some detail, as possible ways to reduce the effects of the Cottonwood landflow. None of the alternatives appear to have any significant adverse environmental impacts. There is, however, doubt about the efficiency and feasibility of the various alternatives because of a lack of basic, long-term data. The alternatives are:

Alternative 1 - Bypass Pipeline Around the Toe

Manti Creek would be diverted through a pipeline north of the existing stream channel to keep most of the flow away from the toe of the slide. This would eliminate the toe of the Cottonwood landflow as a source of sediment and reduce downward erosion of the creek channel in this area. Construction cost was estimated at \$1,249,000 and annual equivalent costs at \$98,700. The pipeline would have to cross the potentially unstable "North Slide" area.

Alternative 2 - Debris Dam

A debris dam would be built across Manti Creek near the mouth of the canyon to attempt to settle sediment out before it reached the irrigation system. Construction and annual equivalent costs were estimated as \$740,000 and \$118,800 respectively. This debris basin would have to be cleaned periodically. Geologic conditions are not good for a dam and reservoir. The dam would probably remove little of the clay size sediments which are the most troublesome to irrigation users.

Alternative 3 - Debris Dam on Cottonwood Creek

This dam would trap sediments coming from the upper reaches of Cottonwood Creek. No detailed evaluation was made because no suitable reservoir site is available and because Alternative 6 could accomplish the same objectives.

Alternative 4 - Stabilize Manti Creek

In this alternative, the stream bed of Manti Creek would be armored with heavy riprap along the toe of the slide; this would prevent erosion and consequently reduce sediment concentrations by eliminating the toe of the slide as a source of sediment. The estimated construction cost is \$2,000,000 with an annual equivalent cost of \$167,200.

Alternative 5 - Divert Water From the Head of the Landflow

The Slide Fork of Cottonwood Creek would be diverted above the head of the slide, on top of the rock cliffs above the slide. Construction access would be difficult, very little

flow would be diverted and consequently little reduction in sediment would occur. Alternative 6 can do the same thing better; therefore, Alternative 5 was not examined in detail.

Alternative 6 - Divert Cottonwood Creek

The Slide Fork of Cottonwood Creek would be diverted around the mudflow, into Burnt Hill Fork and Burnt Hill Fork would then be diverted around Conrad Reservoir which is now filled with silt. Both the mudflow and Conrad Reservoir are potential sediment sources. Construction costs would be about \$91,300 and the annual equivalent cost is estimated at about \$22,400. This scheme would reduce sediment only to the extent that the mudflow and Conrad Reservoir are sediment sources.

Alternative 7 - Do Nothing

No structural measures would be taken in this alternative. Maintenance costs for cleaning of the powerhouse diversion canal and irrigation laterals and irrigation furrows is estimated to cost about \$16,000 per year based on the experience of 1976. Costs would decrease to pre-slide levels if sediment loads decreased to pre-slide levels. No capital investment is required.

Alternative 8 - Water Treatment Plant

This alternative would entail building a treatment plant employing flocculation-coagulation to settle sediments from the water in large concrete basins similar to those used in a large city treatment plant to treat turbid water. Because the capital cost and operating costs would be prohibitive, this alternative was not examined in detail.

Alternative 9 - Polymer Treatment

Polymer chemicals would be added above the existing debris basin; these chemicals will promote settling of silt and clay size particles which would otherwise pass through the debris dam reservoir. The initial cost is estimated at \$32,000, and the annual equivalent cost as \$91,200.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The basic conclusions of this study are:

- The risk of possible damming and subsequent damaging flooding caused by the landslide is very small.
- Major movements of the Cottonwood landflow may have stopped.
- The amount of sediment carried by Manti Creek appears to be decreasing and sediment levels will continue to decrease with time if the Cottonwood landflow stops moving.
- The damages caused by increased sediment levels appears to have been minor and do not appear to justify large expenditures for corrective measures.
- There is insufficient basic data on sediment levels, sources of sediment, movement of the Cottonwood landflow, and the effects of sediment on local agriculture to accurately assess the effectiveness of, or the need for, any corrective action.

Recommendations

The two primary recommendations based on data available at this time are:

- Adopt the "Do Nothing" alternative.
- Establish a methodical monitoring program to obtain basic data to confirm that sediment levels are decreasing, that the Cottonwood landflow is stopping, and that the effects of the landslide are small. If these items are not confirmed by the monitoring program, the data gathered will serve as a rational basis for the selection and design of corrective measures.

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Chapter 1

INTRODUCTION



CHAPTER I

INTRODUCTION

SCOPE AND PURPOSE

In 1974 and 1975 the Cottonwood landflow moved down the south slope of Manti Canyon. The landflow, located in the Manti-La Sal National Forest, has been the concern of the United States Forest Service (USFS) and the nearby City of Manti. See Figure I-1. The Cottonwood landflow is about 1.9 miles long and ranges in width from 300 to 2,400 feet. The head of the landflow is at elevation 8,800 feet with the toe ending in Manti Creek at elevation 7,200 feet. Maximum depth of the landflow has been estimated at 300 feet (Reference 9).

The Forest Service has identified the principal areas of concern associated with the slide movement to be:

- Increased sediment load in Manti Creek, and
- Potential for damaging flooding in the City of Manti.

Residents of Manti and personnel of the U.S. Forest Service have noticed an increase in sediment loads in Manti Creek since the slide movement. The highest concentrations were noted in Fall 1975 during a period of slide movement. High concentrations were also noted during peak stream runoff periods during Spring 1976: sediments accumulated in irrigation laterals and lined furrows, resulting in some short term difficulties in irrigating field crops.

During the period of the slide's greatest movement, the citizens in the City of Manti were alarmed by the potential for a damaging flood. The concern expressed was that the landflow would cross Manti Creek forming a landslide dam, impounding a reservoir of water which could then breach this natural dam, flooding the City of Manti.

The identification of these concerns and their potential impact upon the community prompted the study of both structural and non-structural solutions that would reduce the effects of the landflow. A number of remedies were suggested and all showed some promise. The purpose of this study is to examine the feasibility of alternative solutions--some were suggested from earlier studies and some developed during the course of this study.

The nine alternatives examined include:

- Alternative 1: Bypass pipeline around the toe of the landflow
- Alternative 2: Debris dam on Manti Creek
- Alternative 3: Debris dam on Cottonwood Creek
- Alternative 4: Stabilize Manti Creek
- Alternative 5: Divert water from the head of the landflow
- Alternative 6: Divert Cottonwood Creek
- Alternative 7: Do nothing
- Alternative 8: Treatment plant
- Alternative 9: Polymer treatment

Locations of the alternatives are shown on Figure I-2.

The study involved comprehensive examination of all feasible alternatives. The study approach was designed to fully reflect engineering, environmental, and economic considerations. The investigation consisted of four major tasks, resulting in a recommended course of action. The major tasks were:

- The first task consisted of a review of available information and a reconnaissance-level field investigation. Previous studies and material were reviewed; Federal, State, and local agencies were contacted. Field investigations involved engineering, geological, and environmental reconnaissance. The information provided an understanding of the effects of the landflow and data necessary to evaluate the effectiveness of alternative solutions. An important part of this phase was quantifying effects of the landflow and viewing these effects in perspective with the hydrologic, geologic, and environmental conditions existing before the slide.
- The second task consisted of examining each alternative at a conceptual level to eliminate those alternatives which did not warrant further study. Alternatives were evaluated on the basis of costs, level of effectiveness, reliability, and environmental impact. Six alternatives were selected for further study.
- The third task consisted of an engineering analysis and environmental assessment of the six feasible alternatives.

- Lastly, cost estimates for the feasible alternatives were prepared for capital improvements and operating requirements.

PROJECT AREA

General

The Cottonwood landflow is located in Manti Canyon in the Manti-La Sal National Forest, Sanpete County, Utah. The City of Manti is located below the mouth of Manti Canyon as shown on Figure I-2. The area of study includes Manti Canyon, the City of Manti, and agricultural lands irrigated by Manti Creek.

Manti Canyon

Manti Canyon and the Cottonwood Creek drainage have been used primarily for recreational and livestock grazing purposes: Yearns Reservoir has been stocked annually with fish; elk and deer have been hunted in the Manti Canyon area.

Springs in Manti Canyon supply the City of Manti with domestic water. These springs are located near the headwaters of the Burnt Hill Fork of Cottonwood Creek and further up Manti Canyon near Middle Fork, Hougaard Fork, and Milk Creek.

Manti Creek supplies irrigation water for the City of Manti and the surrounding farm lands. Reservoirs were constructed on Cottonwood Creek to store additional irrigation water during periods of low runoff. Conrad Reservoir was constructed

in the early 1900's but filled with sediments and was subsequently abandoned. Cottonwood Reservoir was constructed in the early 1900's to store irrigation water. The reservoir was drained in 1975 when the lower Cottonwood landflow began moving.

Two debris dams were constructed in the late 1800's at the mouth of Manti Canyon. The lower debris dam, filled with sediment, was abandoned as a sediment reservoir. The upper debris dam is still operational. From 500 to 1,000 cubic yards of sediment are reportedly cleaned from the reservoir every 4 or 5 years. Sediment cleaned from the basin was mainly sand and gravel size material, and was used for road surfacing near Manti.

Since the Cottonwood landflow has been active, however, yearly cleaning has been required in the upper debris basin. The first cleaning, in Fall 1975 was done by the Utah National Guard; the second cleaning, in Fall 1976, was done by the U.S. Forest Service.

City of Manti

The City of Manti, located near the mouth of Manti Canyon and founded in 1849, was the first settlement in Sanpete County. The City of Manti has grown to a population of about 1,800. Other than turkey production, farming is the main source of livelihood in the area.

Agricultural Lands

Manti Creek irrigates about 6,600 acres of cropland. Irrigated crops include alfalfa, grain, corn silage and improved

pasture. Water diverted from Manti Creek near the mouth of Manti Canyon is transported by irrigation laterals to adjacent farmlands. Excess irrigation water is collected in drainage ditches, then flows to Gunnison Reservoir.

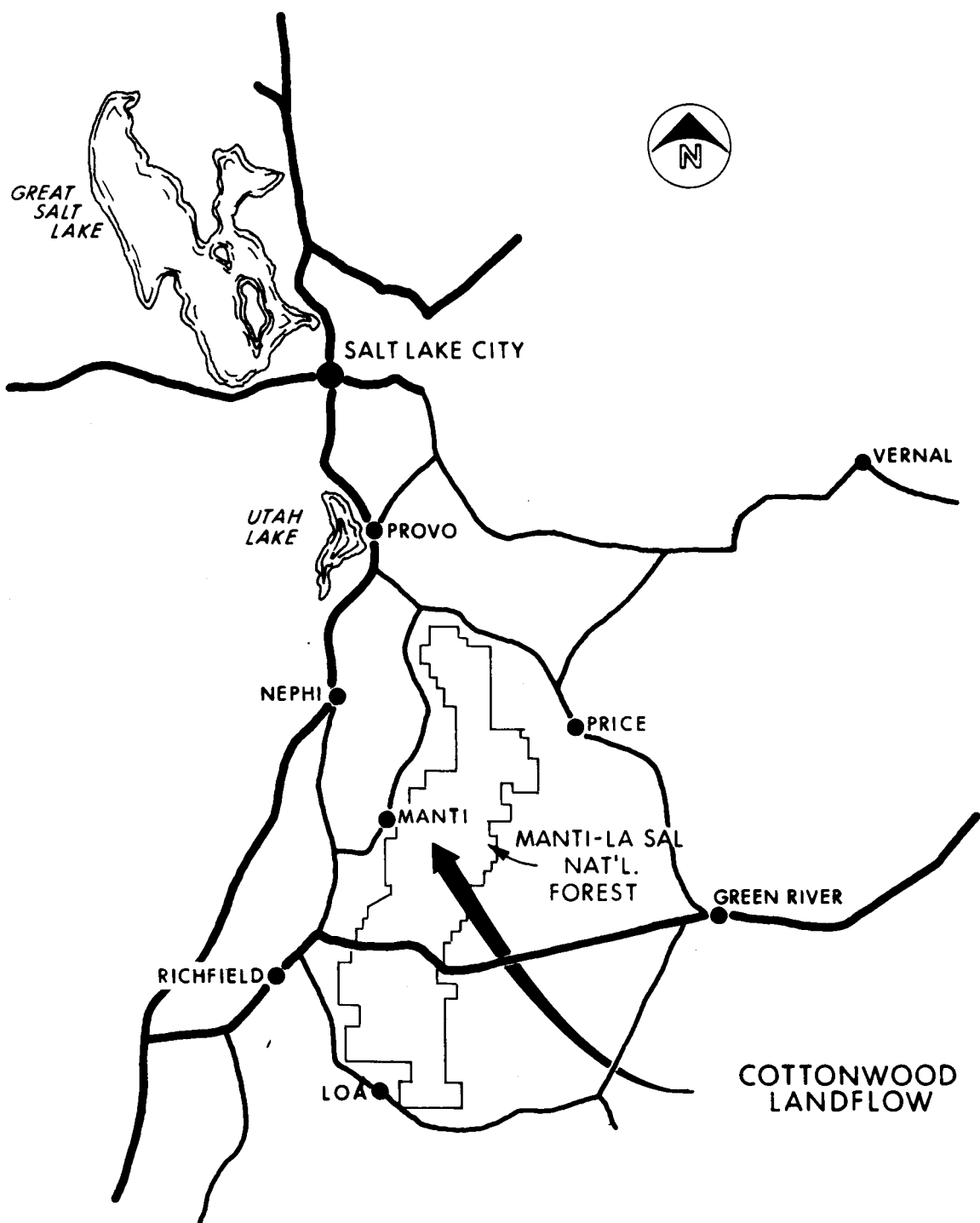


FIGURE I-1
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
VICINITY MAP

Chapter 2

BACKGROUND INFORMATION



CHAPTER 2

BACKGROUND INFORMATION

GENERAL

Review of Available Information

During the past eighteen months, many reports, letters, and memoranda have been written concerning the various aspects of the Cottonwood landflow (see Appendix A). Part of this study included the review and evaluation of all available information. The background information presented in Chapter 2 is the product of previous work and independent field investigations conducted by CH2M HILL.

Field Investigation

The regional geology in Manti Canyon was studied. Soil types in the Cottonwood landflow and nearby drainage areas were also examined. The Cottonwood landflow was mapped; scarps, shear zones and sources of water were identified.

Environmental studies in Manti Canyon were made of plant, animal, and aquatic communities. On-site surveys were conducted in the slide area to determine the potential impact alternative solutions might have upon plant and animal communities. Plant and animal population composition, density, and structure were identified along with their geographic distribution. Benthic macroinvertebrates (stream bottom organisms) and fishes in Manti Creek were surveyed to document species type, species density and general quality of the aquatic regimen. Fishes were surveyed by electro-fishing and benthos were sampled by standard techniques.

Field reconnaissance included visual observations of sediment conditions and water quality in Manti Creek and scenic quality, locations of community utilities and facilities, and recreational activities in Manti Canyon.

Citizen Survey

Personal conversations were conducted with a small number of Manti residents to determine their attitudes concerning the Cottonwood landflow: Do they feel it represents a hazard to the community? What problems has the slide created for the community? Do they feel something should be done to correct the problems? The results of these conversations are summarized at the end of this chapter.

GEOLOGY AND SOILS

Geology

Manti Canyon is located near the west margin of the Wasatch Plateau in an area known as the Wasatch Monocline. The canyon trends east-west terminating to the west in the Sanpete Valley. Two geologic rock units are exposed in Manti Canyon, the North Horn Formation and the Flagstaff Limestone.

The North Horn Formation is about 3,000 feet thick and is comprised of interbedded layers of sandstone, siltstone, and shale. The North Horn Formation is presumed to be a deltaic deposit or an alluvial fan.

The Flagstaff Limestone overlies the North Horn Formation and ranges in thickness from 300 to 800 feet. The Flagstaff Limestone is of non-marine origin and contains beds of

conglomerate, sandstone, shale, and gypsum. The Flagstaff Limestone, a relatively resistant formation, forms the cliffs at the canyon rim in Manti Canyon. The head of the Cottonwood landflow is a near vertical exposure of the Flagstaff Limestone. Exposures of the North Horn Formation and Flagstaff Limestone have a north-westerly dip ranging from 15 to 20° in the Manti Canyon area.

The Wasatch Monocline has been normal faulted producing a sawtooth appearance in the ridges of Manti Canyon. Three fault traces pass through the slide--one at the head of the slide, one near the center and one at the toe, see Figure II-2.

The Cottonwood landflow is not the only landslide in Manti Canyon. The U.S. Forest Service has mapped about 60 potential landslides in Manti Canyon, see Figure II-2.

Several active geologic agents may be involved in the landslides in Manti Canyon. These are:

- Stratigraphic. The formations on the south side of Manti canyon gently dip downslope.
- Structural. The north-south faulting has fractured rocks of the overlying, competent Flagstaff Limestone. The fracturing has created weak zones. Rockfalls are more likely to occur in these weak zones than in areas of sound rock.
- Topographic. The north-south faulting has disturbed natural drainage courses. Scarps and fault traces increase the infiltration of surface water into the ground water system.

The topography is geologically youthful with steep slopes which are less stable than flatter slopes found in geologically mature terrain.

- Lithologic. The North Horn Formation consists of sandstones interbedded with relatively weak shales.
- Climatic. Most of the slides in Manti Canyon are on the south side. Snow accumulates on the shaded slopes, increasing the supply of surface and ground water.

The Cottonwood Landflow

Before the massive landflow in 1974 and 1975, creep movement had been noted in the upper portion of the landflow. About 9 feet of pipeline had been added to the Manti City water pipeline in the 35 years of service prior to 1974 (Reference 14).

In 1974 and 1975 three separate sequences of movement occurred: in early June 1974, a rockfall-mudflow; on June 10, 1974 movement in the upper landflow; and in July and August of 1975 movement at the toe of the landflow began.

The rockfall occurred in the near vertical cliffs above the Cottonwood landflow. The rockfall was accompanied by a mudflow which moved trees, boulders, mud, and debris to the area of the old Conrad Reservoir. The rockfall and mudflow were not a part of the Cottonwood landflow (see Figure II-1). Four days after the rockfall and mudflow were noticed, the upper portion of the Cottonwood landflow moved and broke the

Manti City water pipeline. Movement continued in the upper landflow through Spring 1975. The maximum observed rate of movement in the upper landflow was about 8 feet per day, with total displacement ranging from 300 to 500 feet.

In June and July 1975 movement at the toe was observed and movement of the entire Cottonwood landflow began. Movement at the toe occurred in masses ranging from 300 to 500 feet wide with a maximum rate of movement observed in the Cottonwood flats area of about 4 feet per day. Total displacement at the toe ranged from 200 to 300 feet.

Movement of the Cottonwood landflow was monitored by the U.S. Forest Service from May 1976 to August 1976. Total monitored displacement in the upper landflow area was about 5 feet, total displacement at the toe was generally less than 1 foot. Monitoring ended in August 1976 (Reference 13).

The triggering mechanism appears to have been the reported heavy warm rains in March 1974, which caused the rockfall. This then caused a mudflow down Cottonwood Creek. The mudflow disrupted the surface drainage at the head of the landflow, resulting in increased infiltration and increased ground water levels. The seepage forces (driving forces) increased and movement began. Movement further disrupted drainage, resulting in a progressive sliding down the slope.

Massive movement slowed in Fall 1975 and the slide mass began to stabilize. As the ground water drained from the slide mass, seepage forces and excess pore pressures began dissipating. Surface water was diverted from the head of the landflow, further reducing the source of water.

The movement of the Cottonwood landflow follows the general sequence of events in most landslides. There is a temporary increase in pore pressures and seepage forces, followed by rapid, massive movement and subsequent stabilization. The Cottonwood landflow is probably stabilizing and should become more stable with time as surface drainage develops and infiltration decreases.

Based on the history of movement and the general behavior of landslides, movement of the landflow should decrease with time but is not expected to completely stop. Creep movement, as observed in the landflow prior to 1974 and presently observed in the "Old North Slide," is expected to continue.

Movements greater than a gradual downhill creeping may possibly occur following heavy rain or snowmelt, but would probably be smaller than that which happened in 1974 and 1975.

HYDROLOGY

This section refers to the hydrology of Manti Creek.

Drainage Areas

Drainage areas were determined from the 1:24,000 U.S. Geologic Survey (U.S.G.S.) topographic maps of the Black Mountain, Ephraim, Danish Knoll, and Ferron Reservoir Quadrangles for the various points as follows:

- Manti Creek at lower power house
(mouth of canyon) 31.4 square miles
- Manti Creek at U.S.G.S. stream
gauging station 25.6 square miles

Using an envelope curve for peak discharges per square mile versus drainage areas for other basins in this region, Rector estimated a peak discharge of 5,280 cfs for Manti Creek.

Based on the above data, the following flood flows were selected for purposes of this report:

<u>Recurrence Interval, years</u>	<u>Peak Flood Flow, cfs</u>
2	400
10	700
100	1,100
"Probable Maximum Flood"	6,000

Using the selected flood flows and adjusting for the effects of area, a flow of 860 cfs was estimated for the 100-year flood at the east flank of Cottonwood landflow. This is the selected design flow for the toe by-pass pipeline alternative.

The spillway design flood of 6,000 cfs was chosen for the Manti Creek Debris Dam Alternative. Further, detailed studies are necessary to confirm the proper "Probable Maximum Flood" to be used for the spillway design.

The last serious flood in the City of Manti was in 1902, followed by smaller and less serious floods in 1906, 1908, 1909 and 1910 (Reference 3). Grazing management since 1910 may have reduced flood potential to some extent.

The local Soil Conservation Service office has estimated that the flow capacity of existing flood channels in the City of Manti is 800 to 900 cfs (personal communication L. Hunt SCS). This indicates that there are potential flood problems in Manti independent of the Cottonwood landflow.

Manti Creek Profile

The Cottonwood landflow has partially filled in Manti Creek along the toe of the landflow, raising the stream bed. The changes in the creek profile were determined by examining various profiles of the creek. Profile data were:

- 1934 - "Plan and Profile of Manti Creek Including North Fork, Utah, U.S. Geological Survey, 1934
- 1963 - Ephraim Quadrangle, Utah, 7.5 minute series, U.S. Geologic Survey, published 1966, from photographs taken in 1963.
- 1975 - Topographic mapping by U.S. Forest Service dated November 1975
- 1976 - Stadia survey by CH2M HILL in October 1976

These profiles show that Manti Creek has been raised a maximum of about 100 feet by filling from the Cottonwood landflow. Between the 1975 and 1976 surveys, the stream bed raised about 70 feet near the upstream third point of the landflow toe. This probably occurred from a combination of sediment deposition in a flat section and additional movement of the Cottonwood landflow between 1975 and 1976.

Approximate stream gradients from the profiles are:

<u>Location</u>	<u>Approximate Stream Gradient, feet/mile for Various Dates</u>			
	<u>1976</u>	<u>1975</u>	<u>1963</u>	<u>1934</u>
Immediately upstream of landflow	200	200	200	200
Below landflow to gauging station	390	390	390	390
Average gradient through landflow area	600	600	600	600
Maximum gradient through landflow area	1,500	1,500	900	900
Average from above landflow to mouth of canyon	350	350	350	350

Stream Channel Characteristics

Through much of its length, Manti Creek has steep banks which are subject to erosion during high flows. During low flows the creek stays within an armored bed of gravel and cobbles. Some fine-grained sediments can be found in the creek above and below the slide. Areas in the toe of the landflow where the gradient is flat have deposits of fine-grained sediments. At the downstream toe (west side) of the landflow, the stream gradient is steep and the stream bed is armored with large boulders and rock fragments.

The stream flows through alluvium (stream deposited materials) and colluvium (slope wash materials) ranging from clay and silt size to rocks several feet in diameter. The steep banks and evidence that Manti Creek meanders (shifts horizontally) indicate that very large sediment loads can be expected during large floods.

WATER QUALITY

Quantitative data describing sediment concentrations in Manti Creek includes:

- A sediment sampling program conducted jointly by the Soil Conservation Service (SCS) and Utah State University from April 28 - October 12, 1976.
- Seventeen sediment samples taken and tested at the direction of Eugene D. Hansen (USFS) on 27 May and 8 June 1976. Samples were taken during peak flows of 1976, and total sediment concentrations averaged 1,708 milligrams per liter (mg/l) -- 39 percent of the sediment was clay size (smaller than 2 microns).
- Six sediment samples taken by Ned Madsen, President of the Manti Irrigation Company, in October and November 1975. Utah State University analyzed the samples, showing concentrations of 3,800 to 10,800 mg/l. Samples contained only about 0.5 percent clay.
- Data reported by L. Hunt (SCS) for 1964 and 1975 (2 samples).

There is little historic data describing pre-slide sediment conditions in Manti Creek; the available data characterizes only those conditions present during toe movement and post-slide conditions. The most valuable data characterizing this period were the results from the Utah State University sampling program. The standard methods used to collect and analyze the samples were scientifically reliable and the

frequency and duration of the sampling helped to identify trends in sediment concentrations. The remaining data is spotty and methods used to collect and/or analyze the samples were not consistent. Other than a single sample taken in 1964, there is no record of sediment sampling prior to 1974.

The sediment samples collected by Utah State University were taken at seven locations in Manti Canyon (see Figure II-4). Three sampling sites were located on Cottonwood Creek and four sites on Manti Creek. Sampling at Stations 1, 2 and 3 was conducted for five months at one week intervals. Sampling at the remaining sites was infrequent and irregular.

Figure II-5 is a graph of streamflow and sediment concentration for Sampling Stations 1, 2 and 3. The plot shows sediment concentrations peak with the first major increases in Spring runoff (stream discharge). Further increases in discharge cause sharp but smaller jumps in sediment concentrations. The data shows sediment concentrations to exhibit a high, sharp peak in the late Spring followed by a series of smaller peaks with rapidly decreasing concentrations as stream discharge declines.

The values for Station 1 (above the landflow) are representative of the stream and its setting. Values at Station 2 and 3 (below the landflow) suggest the effects of the Cottonwood landflow. Pre-slide conditions, however, including steep, easily eroded stream banks and evidence of meanders, characterize much of the lower reaches of Manti Creek indicating that a large source of sediment existed before the landflow occurred. This source of sediment will remain after the landflow stabilizes. Without pre-slide data it is difficult to determine the amount of sediment contributed to Manti Creek by the landflow. Samples taken at the remaining

stations are shown in Table II-1. The findings show the Slide Fork of Cottonwood Creek has higher sediment concentrations than the Burnt Hill Fork. Low streamflow probably contributed to the minor differences in values. The measurements at Station C are generally higher than those at either Station A or B. The east flank of the slide disrupted the lower reach of Cottonwood Creek and probably may have been the major contributor to the high sediment values at Station C.

Based on the Utah State University data at Station 2, an estimated 7 acre-feet of sediment was carried by Manti Creek in 1976. Crude adjustments in this figure to account for yearly flow differences would indicate that sediment may range from 4 to 33 acre-feet per year, with an average of about 19 acre-feet per year. Assuming an average sediment production of 0.5 to 1.0 acre-feet per year, per square mile of drainage area in the basin, a yield of 16 to 32 acre-feet per year could be expected. An average annual amount of sediment is probably in the range of 10 to 30 acre-feet.

Examination of Figure II-5 shows that the values at Station 3 were always less than those at Station 2 -- especially during the first peak flow period. This suggests a large amount of the sediments are deposited in the reach between Station 2 and 3. Approximately 3 to 4 acre-feet of sediments were estimated to have passed Station 3 in 1976, about 50 percent of that estimated to have passed Station 2.

TABLE II-1
SEDIMENT CONCENTRATION (mg/l)
A through D

DATE	STATION			
	A	B	C	D
	CONCENTRATION MG/LITER			
6/24/76	46	58	113	111
7/8/76	14	14	173	30
7/15/76	14	27	72	25
7/19/76	21	14	55	38
7/26/76	18	14	111	61
8/26/76	44	220	21	13
9/2/76	15	18	9	12
9/15/76	8	66	187	16
9/21/76	5	35	-	32
9/27/76	13	27	-	105

Locations of the sampling stations are shown on Figure II-4.

PLANT AND ANIMAL COMMUNITIES

Two main types of plant communities occur in the vicinity of the landflow.

Above elevation 7,500 feet the most widespread and dominant is the aspen community, interspersed white fir (Abies concolor), douglas fir (Pseudotsuga menziesii), and blue spruce (Picea pungens) in varying densities. An occasional limber pine (Pinus flexilis) occurs, but this species is rare. Above elevation 7,500 feet, the plant community is quite similar whether the location is along a stream or 50 to 100 feet from a creek. The usual "streamside" communities characterized by large willows, river birch, and dogwood are absent except at a few sites. This general absence is attributed to the insufficient water in the creeks, notably Cottonwood Creek, to support the "streamside" type of vegetation.

Below an elevation of approximately 7,600 feet (depending on exposure), gambel oak (Quercus gambelii) becomes more abundant, gradually replacing the aspen in the area of the slide toe. Below the slide toe, pinion pine (Pinus edulis) and Utah juniper (Juniperus osteosperma) becomes dominant. The distribution of the plant communities in relation to the landflow is shown on Figure II-6. No endangered plant species were found in the study area.

The aspen provides some 80 to 90 percent canopy cover. They range in age from 30 to 40 years and are from 20 to 30 feet tall. The younger conifers among the aspen have established themselves as the aspen were killed by various fungus pathogens.

Above Burnt Hill Road, douglas fir comprise 10 to 20 percent of the tree cover. The population is predominately 20 to 30 years old; however, one old patriarch of nearly 80 years old, and a 45-year-old blue spruce were noted. In the upper reaches of Cottonwood Creek, a douglas fir and white fir community provides about an 80 percent cover. A former streamside community of willow (Salix lutea) and cottonwood (Populus alba) have been essentially buried by the slide.

Below the Burnt Hill Road, the conifer population, which provides a 20 percent cover, is half douglas fir and half white fir. The understory plants vary with the slope, exposure, and density of the tree canopy. Mountain juniper (Juniperus communis) provides nearly 40 percent of the understory in some sites, and snowberry (Symphoricarpos) 30 percent in other areas. Below about 8,000 feet, Oregon grape (Mahonia repens) and serviceberry are dominant understory species.

Below Yearn's Reservoir and along Manti Creek, a characteristic streamside community of narrowleaf cottonwood dominate. Associated species mostly include river birch (Betula occidentalis) and redosier dogwood (Cornus stolonifera). This community was destroyed where the landflow was most destructive and ended where the stream slope was too great to provide sufficient water for plant development. The cottonwoods extend along the length of Manti Creek to the National Forest boundary.

Studies of animal populations were conducted in each of these plant communities. Trapping and release, animal signs, and direct observation were used to identify the presence and

densities of wildlife populations. In the aspen-fir zone the animal community was noted to be fairly constant. The most common species was the deer mouse (Peromyscus maniculatus) with a population density of 5 to 12 per acre depending on specific habitat. Also present in abundance were the chickaree (Tamiasciurus hudsonicus), western harvest mouse (Reithrodontomys megalotis), montune vole (Microtus montanus), and brush mouse (Peromyscus boylii). The species differed slightly in the pinion juniper community where the pinion mouse (Peromyscus truei) was more prevalent. In the transition area between 7,500 and 7,800 feet in elevation, the northern flying squirrel (Glaucomys sabrinus) was common with a population density of 4 per acre.

Species recorded from observation or presence of signs, but not caught, included: Nuttall's cottontail, rock squirrel, bushy-tailed woodrat, coyote, long-tailed weasel, northern pocket gopher, badger, porcupine, mule deer, elk, and beaver. Only one animal species was noted to be restricted to stream-side habitat -- the beaver.

Birds of many varieties were observed in the study area. Birds and other wildlife species are listed in Appendix B, by the method of observation and habitat. No endangered wildlife species were found in the study area.

FISH AND BENTHIC MACROINVERTEBRATES

Fishes in Manti Creek and Benthic Macroinvertebrates (stream bottom organisms) in both Manti and Cottonwood Creeks were surveyed in October of 1976. Fishes were surveyed in Manti Creek by use of a back-pack electrofishing unit. Fishes were captured, identified, and released after approximate lengths were noted. Sites fished are generally located on

Figure II-7. Twenty-six trout were caught and released at four different sampling stations, with 68 percent of those captured at one location within the toe of the slide. Trout size ranged from 1-1/2 to 15 inches. Although the stream is stocked with larger trout, the presence of 1-1/2 inch trout indicates that natural reproduction occurs in Manti Creek.

Benthic Macroinvertebrates were sampled at eight sites on Manti Creek, and two sites on Cottonwood Creek (see Sample Station locations, Figure II-7). All the stations were riffle sites except sites 2 and 8. Invertebrates were identified to their order and stored for further detailed identification. Macroinvertebrates in riffle areas were primarily caddisfly, stonefly, and magfly, while the pond fauna mostly consisted of worms and true flies. Densities, number per square meter, (No./M²) of fauna in Manti Creek at the toe of the slide compared favorably with those above and below the slide and in Cottonwood Creek.

Aquatic Resources

The locations and population densities of macroinvertebrates inhabiting Manti Creek are noted in Table II-2. Pools had more worms but fewer of the other fauna. Differences in riffle and pool fauna was due principally to variations in substrata and water current. The fauna, in all cases, were considered as a viable community typical of this type of stream.

The data showed no apparent differences or trends in total densities of macroinvertebrates for sites below, above, or in the landflow area. Station No. 6, however, did show

TABLE II-2
 BENTHIC MACROINVERTEBRATES IN MANTI CREEK, UTAH
 OCTOBER 14, 1976. Stations 2 and 8 were pools.
 Cottonwood Creek was sampled October 15, 1976.
 (Density=Number/Meter²)

TAXA	1	2	4	MANTI CREEK					5	COTTONWOOD CREEK Upper	CREEK Lower
				3	8	7	6				
Platyhelminthes (flatworm)	20		30	10						10	30
Insecta-Immatures											
Plecoptera (stonefly)	75	40		100	10	65	40	10	10		80
Ephemeroptera (magfly)	105		120	280		290	1790	95	120		20
Trichoptera (caddisfly)	120		65	160		10	75	120	43		35
Diptera (trueflies)		550	105	20	105	50	20	10	10		75
Coleoptera (beetles)		75									
Annelida Oligochaeta (worms)		1355		10	75						10
TOTAL NUMBER/M ²	345	2020	325	580	195	420	1925	240	190		260

higher densities of fauna. The difference is attributed to the favorable substrata conditions -- gravel-sized substrata 2-4 inches deep overlying a soft, claylike base. Total densities of macroinvertebrates at the Cottonwood Creek sites compared favorably with those found in Manti Creek.

Table II-3 shows the number of rainbow trout caught and released at sampling stations. The greatest numbers of trout were captured in the slide area (15), the least number below the slide (1). The presence of trout within the slide area indicates that this area is habitable. The trout fishery in Manti Creek is maintained through yearly stocking of an average of 2,400 9 inch - 12 inch fish by the Utah State Department of Fish and Game, usually at locations on the north and south forks of Manti Creek. Fish have not been planted in the area below the slide in the past six years because of the prevalence of flash flooding.

Natural reproduction, although it does occur, is insufficient to maintain a fishery at the level needed for the fishing pressure in the streams. Habitats needed for successful spawning include several inches of clean gravel where the current is swift. These types of habitats are sparse, even in undisturbed sections of Manti Creek. Reproduction is further hindered by the relatively high concentrations of stream sediments that occur during the spawning period.

In conclusion, the length of Manti Creek in the vicinity of the landflow and the reach below has limited value as a fishery.

AGRICULTURE

Agriculture is the largest industry in the Sanpete Valley. Approximately 6,600 irrigated acres of farmland surround the

TABLE II-3

Number of rainbow trout at several locations in Manti Creek,
Utah, October 15, 1976.

<u>Location</u>	<u>No. Captured</u>	<u>Length of Stream Fished</u>	<u>Habitat Type</u>
1	3	400 yards	riffle boulders-cobbles
2	1	200 yards	riffle boulders-cobbles
3	15	200 yards	pebble-silt-gravel
4	3	40 yards	pool silt
4	4	200 yards	riffle cobble-gravel-pebble
TOTAL	26		

City of Manti on the north and west. The principal crops include 80 percent alfalfa hay and improved pasture, 12 percent small grain and .5 percent corn with the remaining 7 percent fallow.

Manti Creek is the total source of water supply for the Manti Irrigation Company. Fluctuation in streamflow presents a problem for efficient management of the irrigation supply. A review of irrigation needs has shown a deficit of over 3,500 acre-feet has occurred in 20 percent of the years, a deficit of over 1,000 acre-feet has occurred in 50 percent of the years. An average deficit for all years has been 1,500 acre-feet. Seepage losses in the distribution system have contributed significantly to those deficits.

The irrigation deficit was high during the 1976 calendar year. The light snowfall during the winter of 75-76 contributed to a below normal runoff. The below normal runoff and resulting short supply of irrigation water caused minor crop damage during the 1976 growing season.

Sediment in the main channel of Manti Creek has been a historic stream condition. Most of the canyon is considered to be moderately or heavily erodible. The Manti Debris Basin has been in use for over 80 years for the purpose of reducing these sediments in the irrigation waters. According to a report by the Soil Conservation Service, sediment damages to irrigation ditches were estimated to be \$18,000 annually (Reference 3).

Movement of the Cottonwood landflow has resulted in periodic increases in stream sedimentation. Particularly high stream sediment loads were recorded during:

1. Fall 1975 during movement at the toe of the slide, and
2. Spring runoff in 1976

The greatest concentration of stream sediments was reported in Fall 1975. Sediment was deposited in the lower powerhouse diversion canal, and in irrigation laterals at turnouts or in areas where velocities did not keep silt and clay in suspension; the canals were manually cleaned or flushed to remove the sediment. Sediment was also deposited in crop furrows, forming a relatively impermeable lining in some areas which was corrected by discing or tilling the ground.

In Spring 1976 sediment concentrations were less and shorter in duration than in Fall 1975. Similar problems were observed in the diversion and irrigation canals and croplands but was less severe.

Manti Canyon has been under controlled grazing management since 1910: cattle allotments encompass about 88 percent of the Canyon, sheep allotments about 12 percent (see Figure II-8). Cattle are permitted to graze in the Canyon from late June to late September, sheep are allowed to graze during June only.

A rest-rotation system of grazing is followed. The cattle allotment has eight grazing units--two make up the early range, three the mid-season range, and three the late summer range. Approximately 680 acres of range were disturbed by the landflow and is not available for livestock use. Grasses in the Canyon now show definite signs of overgrazing, especially

along stream banks and meadow areas. Grasses are never allowed to reach a seed-producing stage and overgrazing undoubtedly contributes to the sediment conditions in Manti Creek.

RECREATION

Manti Canyon is a popular area for year-round recreation. Fishing is one of the most popular sports. The North and South Forks of Manti Creek and Loggers and Yearns Reservoirs provide the best fishing in the canyon. Interviews with the Utah Division of Wildlife Resources indicated the areas most heavily fished are above the Cottonwood landflow. The Utah Division of Wildlife Resources has rated Manti Creek as a Class 3 water, on a scale from 1 to 6. Defined as an average to an above-average fishing water -- Manti Creek provides an angler with a satisfactory fishing experience.

This classification is well-suited for waters above the landflow; however, conditions in lower reaches of Manti Creek do not warrant this classification. The frequency of fishing in the vicinity of the slide toe is limited because of inaccessibility. The relatively high number of fish found in the landflow reach during the survey is attributed to low fishing pressure. The accessible areas further below the landslide have a much smaller fish population. This section of the stream is not stocked; the presence of fish is only due to an occasional fish migrating from the upper reaches or washing down during high streamflow. These factors make the recreational aspects of the toe area low in value, particularly for fishing.

In the Fall the presence of elk and mule deer make hunting a popular sport. The area supports a healthy deer herd and approximately 250 to 300 elk.

The canyon is used in the winter months for snowmobiling. The network of Forest Service roads provides excellent routes and access to the high snowfields east of the canyon.

Hikers, sightseers, four-wheelers, and motorcyclists frequent Manti Canyon during most seasons of the year. A Community Campground near Yearns Reservoir provides camping and picnicking facilities for ten family units. A summer-home area has been designated a short distance up the North Fork of Manti Creek. Ten summer homes are located in this area, one isolated home further up the North Fork, and another summer cabin is located on Burnt Hill Flat.

COMMUNITY UTILITIES AND FACILITIES

Community utilities and facilities in Manti Canyon are limited to a Forest Service road network, recreational facilities, a domestic water supply, and small power-generating facilities owned by the City of Manti. The extent of these facilities is discussed on the following pages and shown on Figure II-9.

Manti Domestic Water Supply

The City of Manti receives its domestic water supply from Manti Canyon. Water from springs located near the Middle Fork, Hougaard Fork, Milk Creek, and Burnt Hill is conveyed by a transmission line to the City of Manti (see Figure II-9). Approximately two miles from the mouth of the canyon the water passes through a small power-generating plant. Finally, the water is stored in a storage tank located near the mouth of the canyon.

In 1974 the Cottonwood landflow severed the transmission line. A new line was constructed in 1975 around the landflow,

on the north side of the canyon. Both the quality of water and water supply are adequate to serve the needs of the City.

Energy Resources

There are gas and oil leases covering portions of Manti Canyon. These leases, however, have not been activated and there is no exploration activity in the canyon.

Power Generating Plants

The City of Manti owns and operates two power plants in Manti Canyon. The largest is located at the mouth of the Canyon and a smaller plant is located approximately 2 miles from the mouth of the canyon. The lower powerhouse is supplied with water from Manti Creek; the upper powerhouse utilizes water from the domestic water supply.

Transportation

Access through Manti Canyon is provided by Forest Road #50045, beginning at the Forest boundary and ending at Skyline Drive. This access road is important to both the public and to the Forest Service. It provides an important link to the Skyline Drive, access to Community Campground, summer homes, and to deer and elk hunting. It is essential to the Forest Service for the administration and supervision of resources and fire control.

Shorter side roads are used to lesser degrees but provide good access to some remote regions of the canyon. Road #50133 will be used to harvest timber in Loggers Fork. Road

#50045 may also be used for this purpose. A road providing access to the Burnt Hill area, although primitive, is considered the best route for hauling timber from the south slope west of the slide.

In 1975 the landflow moved to within 25 feet of road #50045 forcing Cottonwood Creek within 20 feet of the road. This activity is approximately 150 yards east of the Cottonwood bridge.

Irrigation Facilities

The Manti Irrigation Company uses Manti Creek as its water supply. Although the irrigation system consists of many miles of canal, the only facilities located in the canyon includes two debris basins at the mouth of the canyon. The upper basin, recently cleaned, has a capacity of 15 acre-feet. The lower basin is filled with sediment and has been abandoned.

VISUAL SETTING

The study area was divided into three spatial units, Lower Canyon, Landflow, and Upper Canyon, to analyze its visual setting. Their boundaries are shown on Figure II-10.

Each of the units was evaluated on the basis of three characteristics: 1) intactness 2) vividness 3) unity. The definition for each of the characteristics follows:

1. Intactness: The relative degree to which the landscape has retained apparent natural conditions.

2. Vividness: The overall extent to which the landscape leaves the viewer with a memorable visual impression.
3. Unity: The compositional harmony that exists between man-made and natural visual resources.

Lower Canyon Unit

This unit consists of the lower 2-1/2 miles of Manti Canyon. This section of the canyon has steep, sparsely vegetated slopes on the north, with more gentle rising forested slopes on the south. Riparian growth is predominant along the canyon floor adjacent to Manti Creek.

From the mouth of the canyon to the eastern end of the unit, there is a gradual vertical rise in the canyon floor elevation.

The lower canyon unit is intact, but compared to the other units, the presence of man-made development is most vivid. Power plants, a water storage facility, pipelines, a diversion canal, sand and gravel excavation, and a major Forest Service road are all located in this unit.

The severity of these man-made features upon the visual quality of the unit is not extensive but is more pronounced than in other units. In this unit there is a strong sense of enclosure created by the ridges to the north and south. The most vivid natural feature in the unit is the north slope.

Landflow Unit

This unit, near the center of the canyon, is comparatively small. Slide activities are most pronounced in this unit, including the most recent Cottonwood landflow as well as

prehistoric slides. The south slope is heavily vegetated and the north slope is more vegetated in this unit than in the Lower Canyon Unit. Vertical rise in the valley floor is fairly severe. Manti Creek flows through some steep walled areas 40-80 feet deep.

Intactness in this unit is fairly good. Man-made development is largely limited to Forest Service roads where switch-back configurations and road cuts are apparent. A water pipeline recently installed through this area has left a barren corridor approximately 10-15 feet wide.

The natural destruction of the Cottonwood landflow and some deep narrow gorges provide the more vivid features in this unit.

Upper Canyon Unit

The Upper Canyon unit is composed of many diverse features all having high visual quality: forked canyons, small reservoirs, diverse vegetation, deep gorges, and high mountain meadows. Man-made development, limited to a campground and a summer-home development blends into the natural surroundings. The Forest Service road network is most extensive in this unit but the varied terrain and extensive vegetation does not allow any long or vivid vistas of this network.

This unit has a high degree of intactness and unity has been achieved between man-made and natural resources. The single most vivid feature of this unit is the diversity of vegetation.

ARCHAEOLOGICAL AND HISTORICAL CONSIDERATIONS

Two surveys for archaeological remnants have been made in Manti Canyon - one in 1975, the other in 1976. Both were done to accompany an earlier study of the Cottonwood landflow (Reference 22). The surveys, conducted near the toe of the Cottonwood landflow and the north slope of the canyon identified two archaeological sites.

One site barely meets the minimum definition of a site: five artifacts were observed and collected from the ground surface. No artifacts were found at varying depths at this site. This site is considered to be completely savaged and of no further scientific interest.

The second site, a small rock structure, was found east of the slide activity. The site is believed to have some potential for qualifying for the National Register of Historic Places.

General conclusions from the surveys, visual observations, and physical conditions present in the canyon indicate little potential for any significant archaeological remnants. Findings have indicated that the presence of man was principally migratory -- hunting and making only temporary camps. The prehistoric and more recent slide activity in the Canyon could be responsible for the destruction of any valuable sites. Generally, those zones which may have some limited archaeological potential would be within 40 to 50 yards from watercourses, and in the lower part of the Canyon near the mouth.

The National Register of Historic Places has been consulted and found to list no significant properties in the area. The debris basin at the mouth of Manti Canyon, however,

constructed in the late 1800's, is considered to have some historic significance. Also, a pioneer's grave is located in this lower part of the Canyon and is believed to have been the first person to be killed by Indians in Manti.

COMMUNITY INVOLVEMENT

Residents of the City of Manti were contacted on an individual basis to obtain their opinions of the landflow and how it affected their community. Their input in this study was necessary since any action taken to correct the landflow will affect them. Mayor Frank Wanlass; Councilman Don Olsen; Ned Madsen, President of the Manti Irrigation Company; and many resident farmers of Manti were contacted. A complete list of residents contacted is given in Appendix A.

People contacted were asked to describe:

- Sediment problems caused by the landflow
 - a) to the irrigation system
 - b) to the farmland
 - c) to the crops
- When the sediment problems occurred
- The type of sediment
- How they corrected the problems created by the sediment

- Sediment problems before the landflow
- Sediment problems after the landflow

Sediment Problems Caused by the Landflow

Farmers in the valley described two irrigation problems resulting from the increased sediment load:

1. Where velocities were slow, irrigation laterals would fill with sediment.
2. Furrows would be lined with sediment, reducing the infiltration of irrigation water.

Generally farmers felt there was no damage to the farmland and only one farmer described any crop damage, that of "burning" due to a young alfalfa crop drying out. Two farmers said livestock would not drink the "milky" water.

When the Sediment Problems Occurred

Most farmers agreed that the sediment problems occurred during Fall 1975, when the toe was moving, and during the Spring freshets of 1976.

Type of Sediment

Descriptions of the sediment ranged from "white chalky muck" to clay or white clay.

How They Corrected the Problem

Farmers described removal of the sediment from irrigation laterals as difficult. It would stick to their shovels and

in some cases a backhoe was required to remove the sediment. Sediment linings in the furrows were tilled, harrowed, or disced into the soil, permitting the infiltration of water.

Sediment Problems Before the Landflow

Some farmers had no sediment problems before the landflow. Others had to clean their irrigation laterals yearly but maintenance was nominal. One farmer constructed a sediment pond on his property to settle out sediments. No farmers described any sediment damage to the farmland or crops before the landflow.

Sediment Problems After the Landflow

Farmers agreed that there was no sediment in the irrigation water after the freshets in Spring 1976 and therefore no sediment problems after this time.

During conversations with the residents many other topics were discussed:

- Of those asked, most people felt the damming and flooding of Manti Creek was not a problem. Most people believed that the increased sediment load in Manti Creek and its effect on their community was a much more serious threat than that of damming and flooding.
- Two of the people felt the U.S. Forest Service was financially liable for any damages caused by the landflow.

- Manti Creek at west flank of Cottonwood landflow 22.8 square miles
- Manti Creek at east flank of Cottonwood landflow (former confluence with Cottonwood Creek) 17.4 square miles
- Cottonwood Creek at Manti Creek 2.0 square miles
- Burnt Hill Fork of Cottonwood Creek at confluence with Slide Fork 1.0 square mile
- Slide Fork of Cottonwood Creek at confluence with Burnt Hill Fork 0.34 square mile

Tributaries

Tributaries of Manti Creek above the mouth of the canyon are: the North Fork, Lowry Fork, Middle Fork, Hougaard Fork, the South Fork, Cottonwood Creek and many small unnamed streams. Cottonwood Creek is presently being diverted into Yearns Reservoir while erosion protection is being built at the confluence of Cottonwood and Manti Creeks. Cottonwood Creek is expected to be returned to its natural course at the completion of the construction activities.

Rainfall

Depth-frequency-duration curves of rainfall are shown on Figure II-3. These values were taken from NOAA Atlas 2, Vol. VI (Reference 23). Because of the steep, mountainous topography of the Manti Creek drainage area, these values should be considered approximate.

Runoff data is based on "Compilation of Hydrologic Data For Manti Creek Near Manti, Utah," December 1975, by John Rector, U.S. Forest Service (Reference 5). Rector's data is based

on recorded streamflow records from 1964 to 1974. The U.S. Geologic Survey stream gauge was abandoned in Fall 1974, reestablished during Spring 1976.

The average annual yield during the period of record is 20,800 acre-feet. May and June are peak runoff periods with 67 percent of the flow occurring in May and June. May, June, and July represent 79 percent of the total annual runoff.

Snowmelt accounts for most of the runoff in this drainage area, which exceeds 10,000 feet in elevation in the eastern end of the basin.

Monthly minimum flows vary from 4 cubic feet per second (cfs) to 63 cfs; monthly means vary from 4.5 cfs to 135 cfs; monthly maximums vary from 5.3 cfs to 239 cfs. The peak flow recorded was 682 cfs on June 9, 1972.

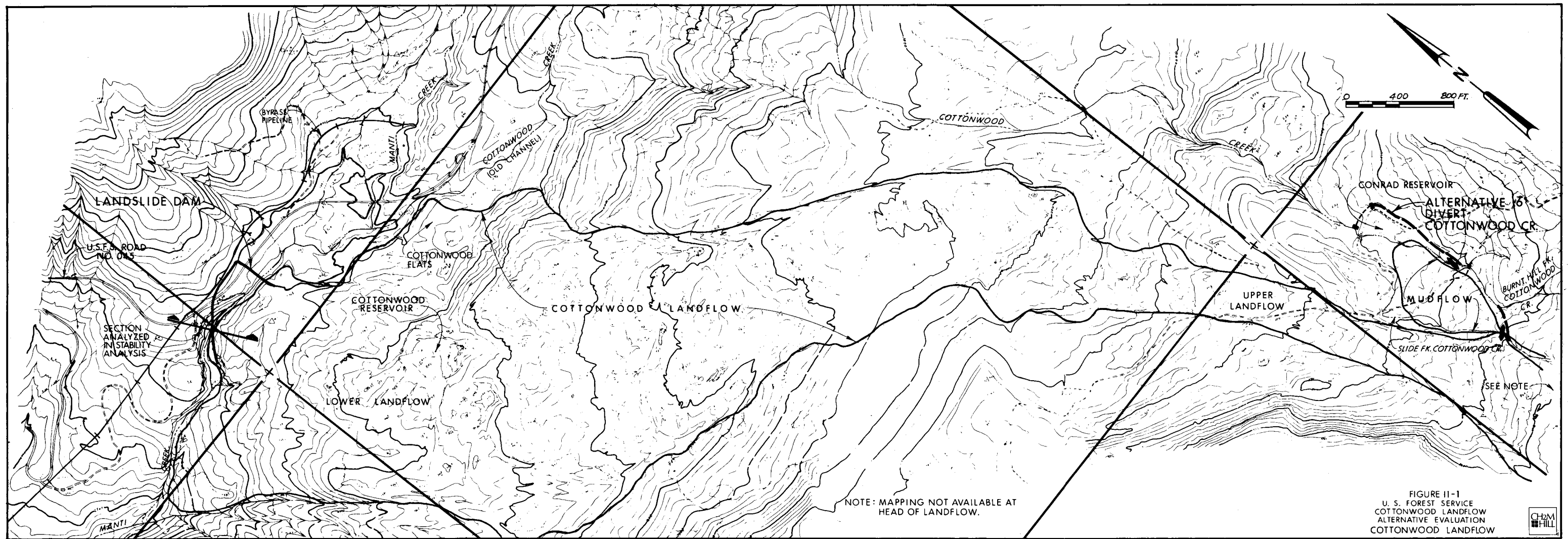
Rector estimated flood flows by a statistical treatment of the 10 years of streamflow records and by a generalized method (Reference 24). The results are:

Return Interval Years	Peak Flow, cfs	
	Statistical Methods*	Generalized Method
2	406	-
5	584	-
10	700	264
20	806	412
50	925	736
100	-	1,120
200	1,113	-
500	-	2,944
1,000	-	4,576

*adjusted by areas to 32 square miles to be consistent with generalized method

- Some people felt that the landflow had stabilized itself and presented no further problems. Others felt that something should be done now, such as constructing the pipeline bypass or stabilizing the toe. The general opinion of the people interviewed, however, was to leave the slide alone since it had stopped and was not causing any problems.

Employees of the Manti City Power Company were also contacted to determine sediment damages to the lower powerhouse. Tony Peterson, Superintendent for the Manti City Power Company, did not know of any damage caused by the increased sediment load. Sediments were, however, deposited in the lower powerhouse diversion canal requiring monthly flushing of the canal.





LANDSLIDES
MAPPED BY THE
U.S. FOREST SERVICE

FIGURE 11-2
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
MANTI CANYON



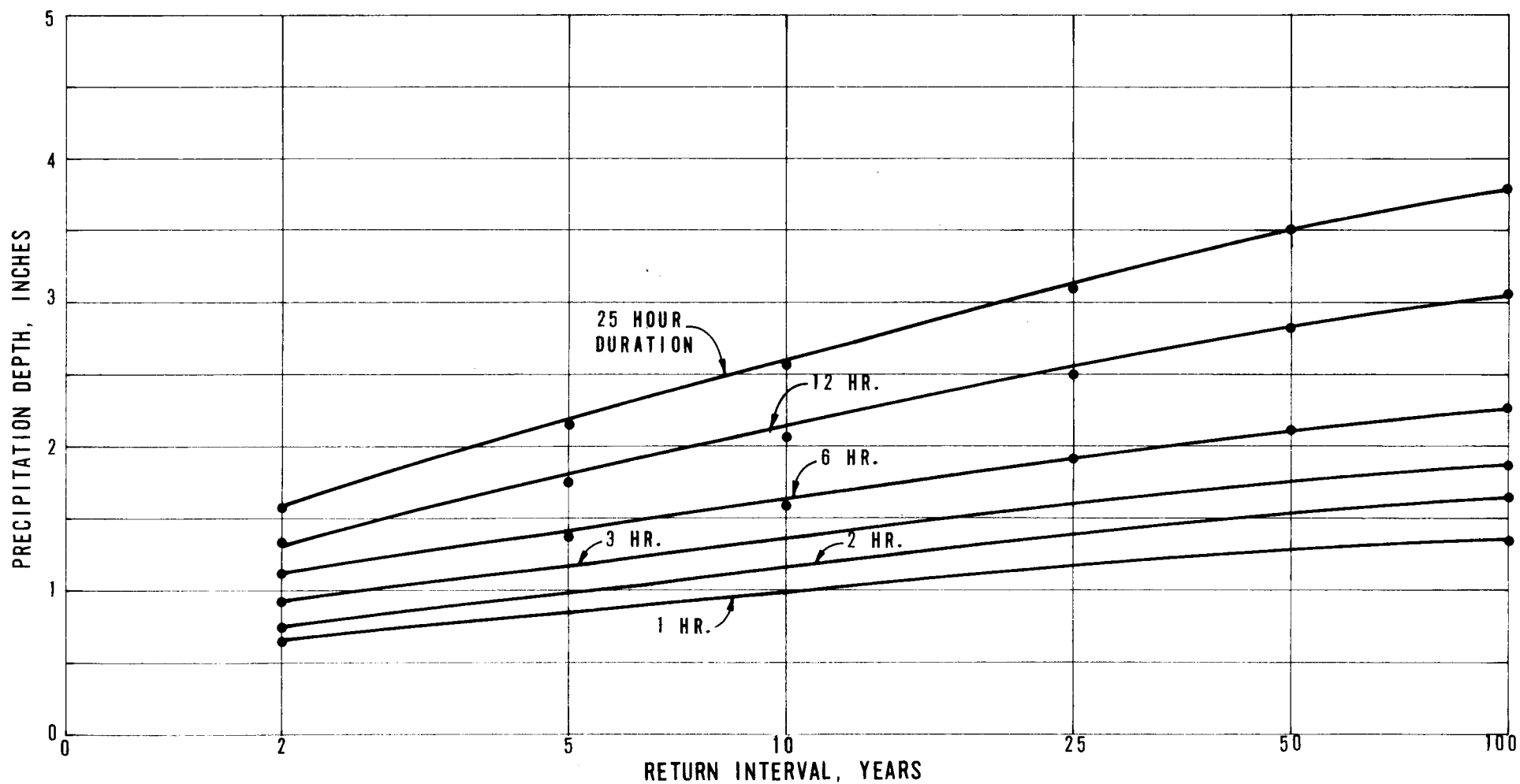
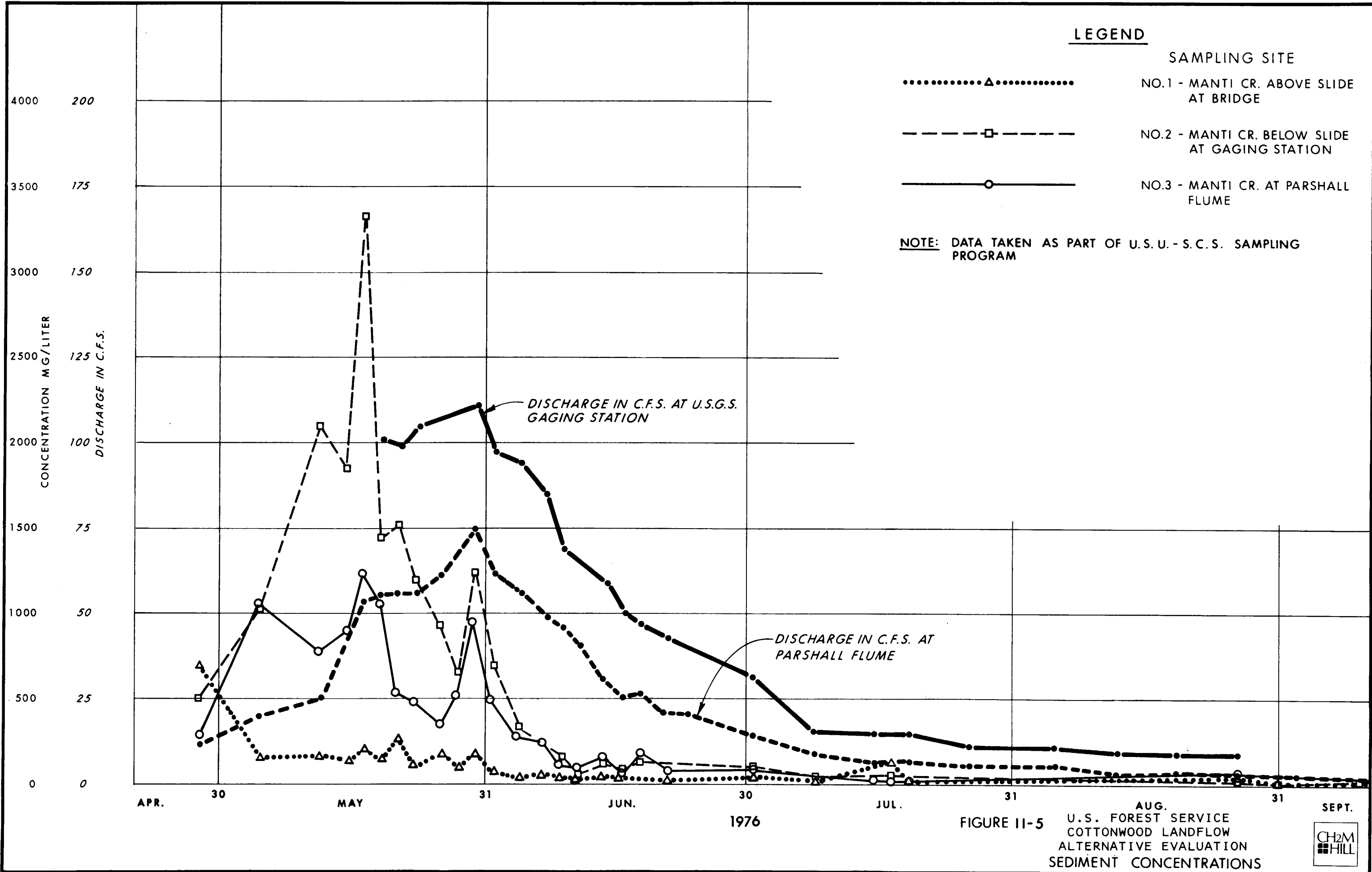
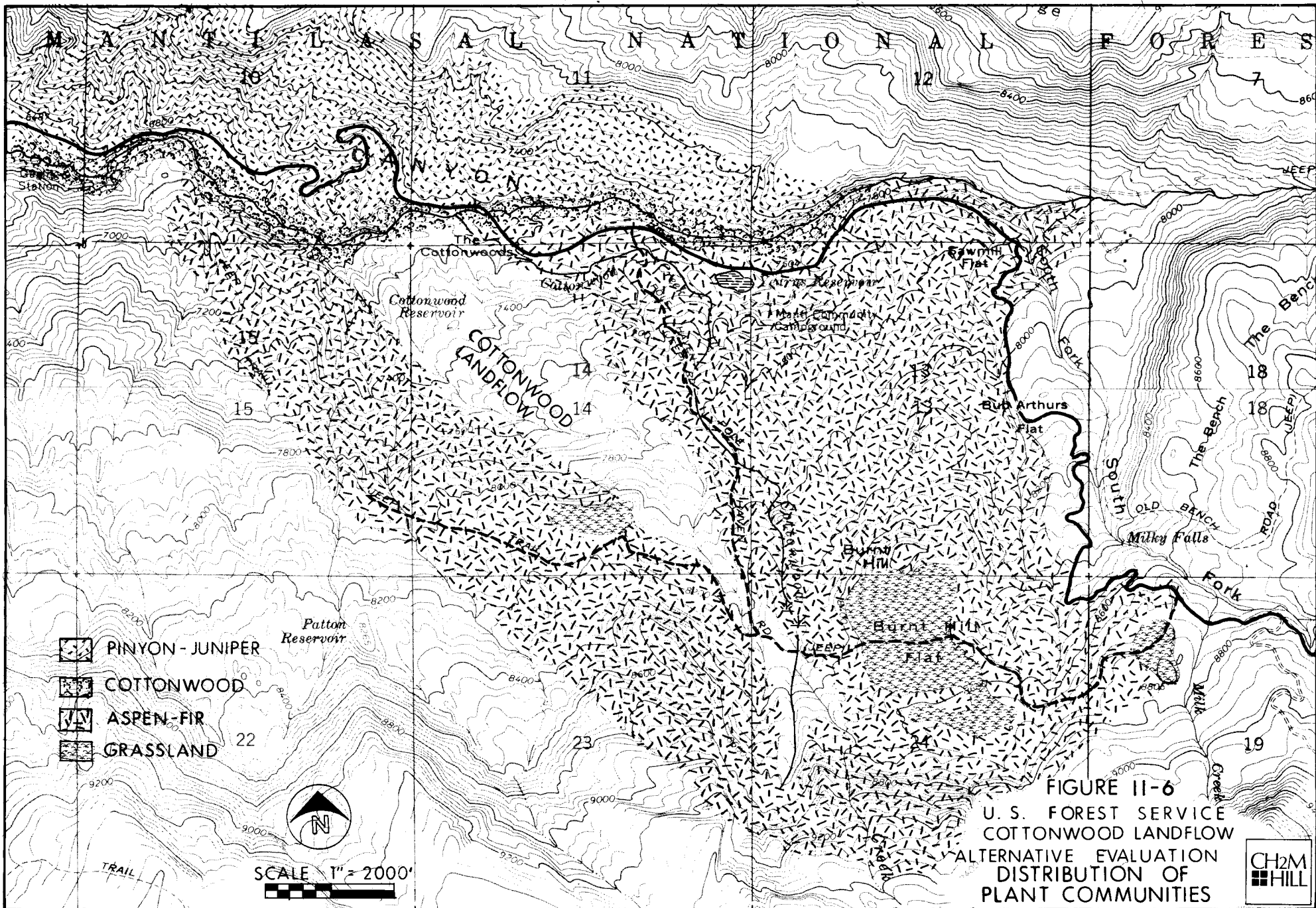
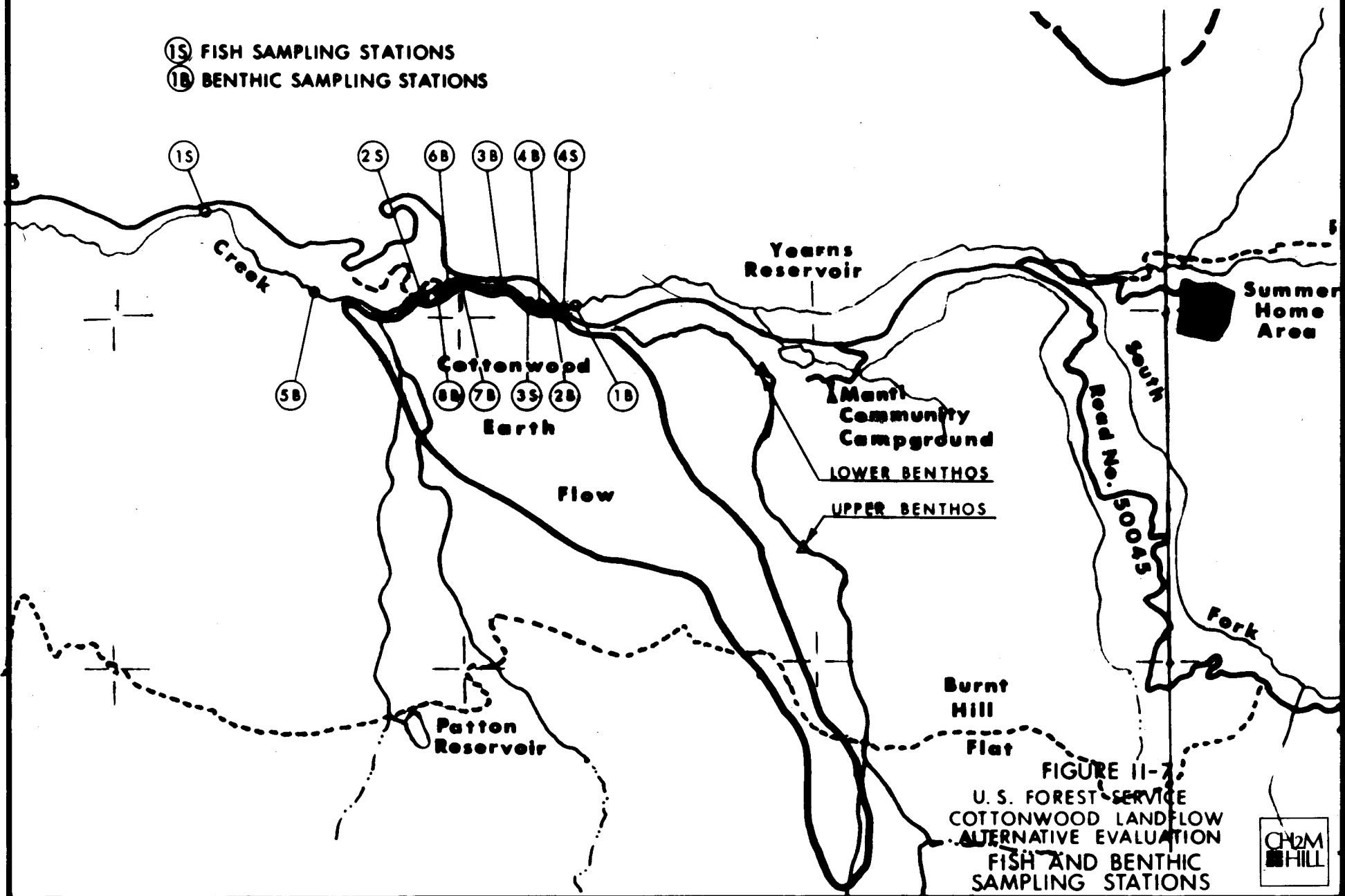


FIGURE II-3
 U.S. FOREST SERVICE
 COTTONWOOD LANDFLOW
 ALTERNATIVE EVALUATION
 DEPTH-FREQUENCY-
 DURATION OF RAINFALL









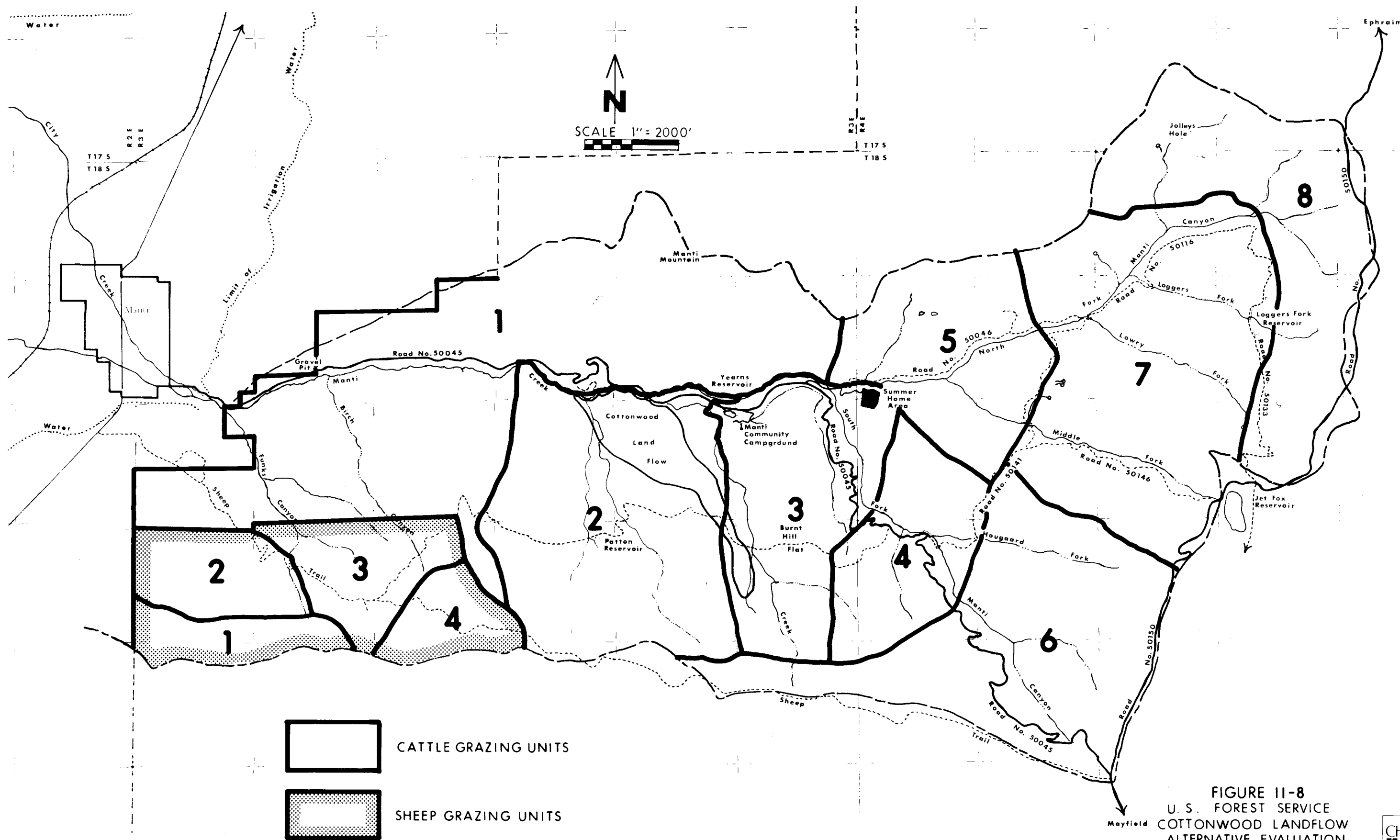


FIGURE 11-8
U. S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
GRAZING ALLOTMENTS

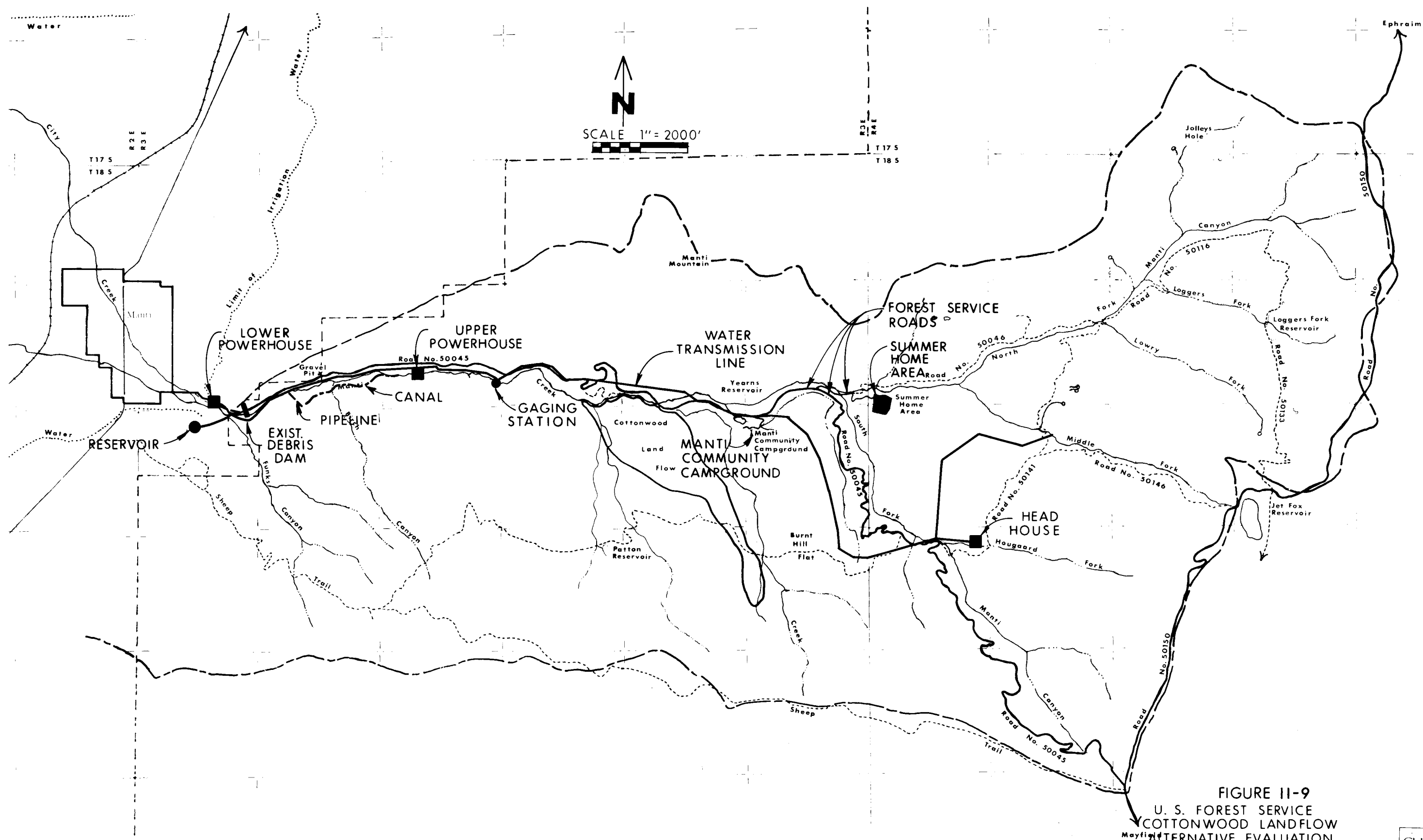


FIGURE II-9
 U. S. FOREST SERVICE
 COTTONWOOD LANDFLOW
 ALTERNATIVE EVALUATION
 COMMUNITY UTILITIES &
 FACILITIES IN MANTI CANYON

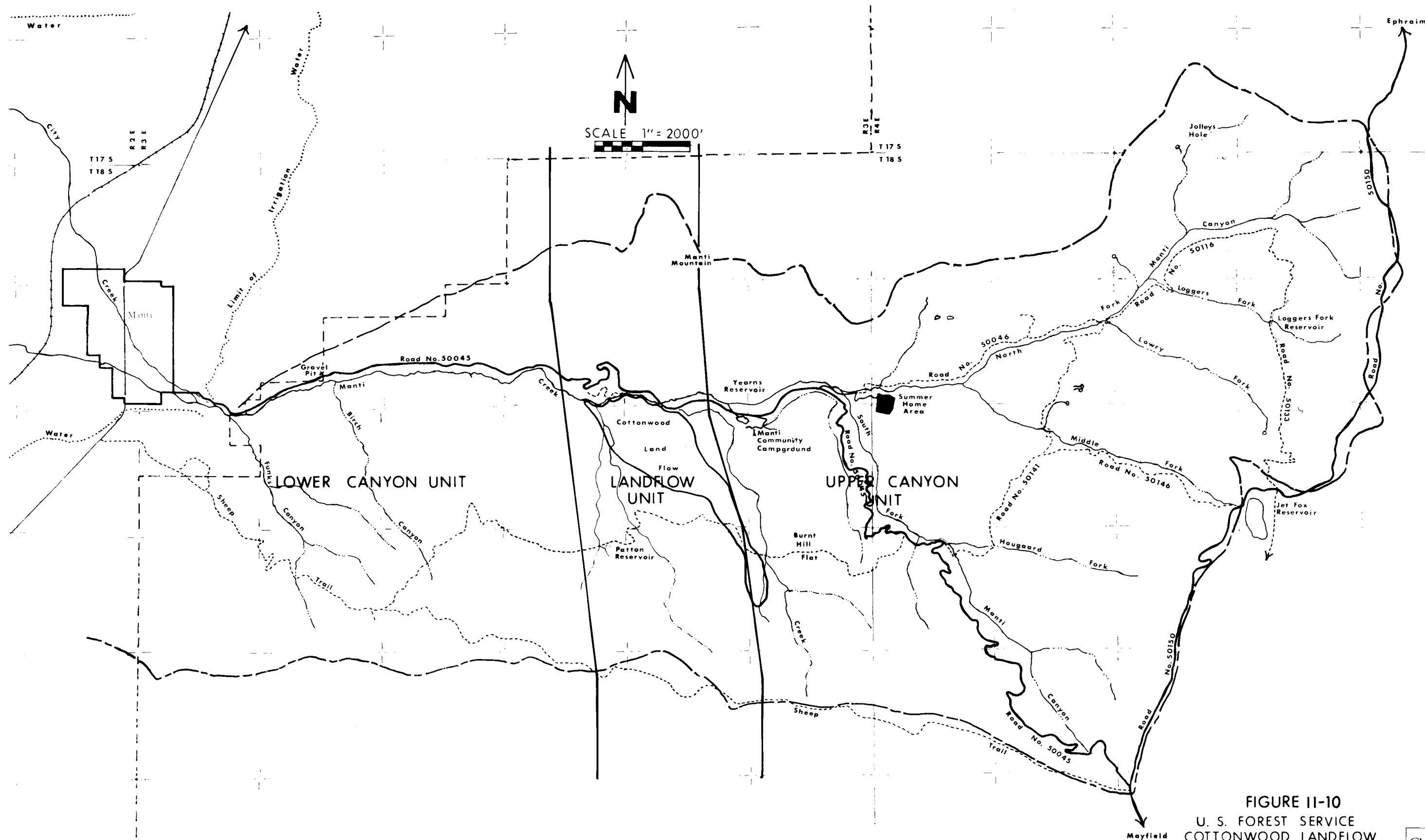


FIGURE II-10
U. S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
VISUAL UNITS

EFFECTS OF
THE COTTONWOOD LANDFLOW

Chapter 3



CHAPTER 3

EFFECTS OF THE COTTONWOOD LANDFLOW

GENERAL

Apart from natural devastation to terrain, vegetation, and water courses, the direct impact of the landflow upon developed areas has been minor. Although direct impact upon developed land can be discounted, secondary effects cannot. Two secondary effects of the landflow movement which have been identified are: 1) high concentrations of sediments in Manti Creek, and 2) the potential of damming and flooding of Manti Creek.

Increased concentration of sediment in Manti Creek has resulted from the landflow disrupting water courses and vegetative cover. The problem was observed during Fall 1975 and Spring 1976. Manti Creek serves as an irrigation water supply and changes in its water quality have caused concern in the Manti farming community -- namely, higher sediment loads in irrigation water can contribute to a reduction in both crop quality and quantity. The other secondary effect of the landflow was identified as a damming and flooding sequence and is in the category of a "potential effect."

The presence of the landflow, the characteristics of its movement, and its observed effects has raised concern in the community of Manti. It is the purpose of this chapter to study the effects of the landflow, the probability of their occurrence and the magnitude of their impact.

LANDFLOW DAMMING AND FLOODING

To better visualize the events required to cause such a catastrophic flooding, a hypothetical damming and flooding

sequence was assumed. The toe of the landflow was assumed to move as previously observed. The site selected for this damming and flooding sequence was the "ideal" dam site: one with the narrowest canyon, retaining the largest volume of water. The site selected is shown in Figure II-1 and labeled "Landslide Dam."

The Manti Creek channel is about 300 feet wide and 45 feet deep at the selected site. The slide was assumed to move across the channel in a 300 foot wide mass, similar to movements observed in 1975. Based on the most rapid toe movement observed, the landflow would take about 75 days to dam the channel. The reservoir created by the landflow dam would impound about 130 acre-feet of water. Eventually, the water would overtop and erode the dam, releasing the impounded water. In order to flood the City of Manti the landflow dam would have to be eroded rapidly so that the combined flow of Manti Creek and water released from the reservoir would exceed the capacity of the Manti City flood channels. Figure III-1 shows times of erosion and discharge resulting from the breaching of the hypothetical dam. During normal peak runoff of 300 to 400 cubic feet per second (cfs), the dam would have to be eroded in four to five hours to release enough additional water to cause flooding of the City of Manti.

The possibility of the damming and flooding sequence occurring is very remote. The reasons are:

- As discussed in Chapter 2, the possibility of a massive landflow movement similar to that observed in 1974 and 1975 decreases with time. As the water drains from the landflow mass and surface drainage patterns develop, the landflow should become more stable and approach pre-slide conditions.

- If movement occurs, the rate of movement will probably be similar to that observed during the Fall of 1974 and 1975 -- less than 5 feet per day. At this rate the landflow would take from 60 to 75 days to dam the channel. During this time heavy earth moving equipment could be mobilized. A temporary spillway could be excavated in the landflow or on the north side of the canyon to prevent the impoundment of water. The toe of the landflow would be eroded and sedimentation would occur downstream, but forming of a dam and impounding of water would be prevented.
- The landflow will probably move in large masses, 300 to 500 feet wide, similar to prior movement. The dam, if formed, will be very wide at the top, not like man-made dams with 20 to 30 foot crest widths.

The composition of the landflow would be fairly well graded from clay size particles to boulders ranging from four to eight feet in diameter. This well graded composition is less erodible than a uniformly graded material. As the fines are eroded, sand, gravels, and boulders fill the voids until a rock-lined channel bottom is formed.

Because of the size of the dam and boulders within the landflow mass, the landslide dam will probably not erode as rapidly as Figure III-1 indicates. A good indication that rapid erosion will not occur is shown in the steep portion of the Manti Creek stream bed at the western toe of the slide. Boulders have formed a protective armament and

have remained through flows estimated at 100 cubic feet per second (cfs). If a dam is formed, the erosion of a new channel will be a slow process taking weeks or months to occur.

- The possibility of a dam forming during periods of peak runoff in Manti Creek is unlikely because of the relationship between hydrologic characteristics of the basin and movement of the landflow. Peak flows resulting from melting snow occur during the months of May and June, whereas movement of the landflow has occurred somewhat later, in July and August. This time lag occurs because runoff from snowmelt is more rapid than infiltration of water into the slide mass.

In summary, the possibility of the damming and flooding of Manti Creek is very improbable and is not considered a threat to the City of Manti:

- The landflow is stabilizing itself and with time the possibility of a massive landflow movement decreases.
- A channel could be excavated in the toe of the landflow to prevent the impoundment of water.
- The possibility of erosion of the dam occurring in less than one day is unlikely.
- The possibility of the landflow moving during periods of peak runoff is remote.

Therefore, the effect of damming and flooding has been eliminated as a criteria for evaluating the feasible alternatives.

SEDIMENTATION

Pre-Slide Conditions

Sediments in the main channel of Manti Creek have been a historic stream condition. Contributing factors include moderate to heavy erosive soils and extensive livestock grazing. Farmers in the valley have been combatting the problem for years. A debris basin was built at the mouth of Manti Canyon over 80 years ago for the purpose of reducing sediments in irrigation water. A report prepared by the Soil Conservation Service in 1973 estimated sediment damages to irrigation ditches to be \$18,000 annually in the Manti irrigation system.

Post-Slide Conditions

Periodic increases of stream sedimentation have occurred since the movement of the landflow. In Summer and Fall of 1974, when only the upper landflow was moving, increased sedimentation was observed in Manti Creek, but was not considered a problem. Periods of notable concentrations of sediment in Manti Creek include Fall 1975, when the toe of the landflow was moving, and in Spring 1976, after the landflow had stabilized.

The greatest stream sediment concentrations were recorded in Fall 1975. Concentrations ranged between 6,000 to 10,000 milligrams per liter (mg/l). Problems observed during this period included sediment deposits in the powerhouse diversion

canal, irrigation laterals, and in cropland furrows. The powerhouse canal was flushed monthly to prevent excessive build-up of deposits. Sediments accumulated in irrigation laterals mainly at turnouts or in areas where silt and clay size material would not remain suspended. These sediments were manually cleaned or flushed from the laterals. In furrows at scattered locations, deposits formed a relatively impermeable lining less than 1/8 inch thick, restricting infiltration of irrigation water. One farmer's crop was reported as slightly damaged. This buildup was disced, harrowed, or tilled to return soils to their original condition. These high sediment concentrations occurred late in the growing season.

Following the normal irrigation period, the waters of Manti Creek were diverted from the irrigation system and passed through the flood control channels -- a normal pattern of operation during the Fall and Winter period.

During the field investigation soil samples were taken from clay deposits at both the landflow and farmlands below Manti. Sieve and hydrometer analysis were performed on these samples with and without a dispersing agent. Results of these tests are shown on Figures III-2 through III-6.

Sediment concentrations observed in Spring 1976 were reported to be less than in Fall 1975. Concentrations were high for a period of four weeks during the spring feshets* - measuring 500 to 1,000 mg/l at the Parshall flume. Irrigation laterals and furrows were cleaned, and croplands were harrowed or tilled as needed.

*Manti Creek Flows during the Spring of 1976 were less than normal - the peak recorded flow in 1976 was 111 cfs compared to a normal peak of 200 to 300 cfs.

Following that period, concentrations decreased. A detailed discussion of sediment concentrations sampled in Manti Creek during a period from May - September 1976, is contained in Chapter 2, in Section Water Quality.

In general, the damaging effect of sedimentation has been relatively minor during the past two years. Problems associated with sediment were short term and considered to be within manageable bounds.

Future Conditions

The limited amount of background data combined with the "state of knowledge" concerning sediment transport does not allow quantitative predictions.

Assuming that the landflow is a major source of sediment, and that the landflow remains stationary, the following conditions can be expected:

- the sediment concentrations in Manti Creek should peak in the late Spring with the first major increase in stream discharge
- sporadic increases in discharge following the initial spring freshets will cause sharp but smaller jumps in the sediment concentrations
- a typical annual graph of sediment will be similar to the data plotted on Figure II-5 - a very high, sharp peak in the late Spring followed by a series of smaller peaks whose maximum concentrations decrease after the first major peak

- Each successive year the sediment concentration curve will be some variation of the above theme. The magnitude of the initial and subsequent peaks are dependent on the stream discharge.

If the landflow were to move again or stream discharge greatly exceed the previous year's flow - a renewed sediment cycle would occur. High sediment values would be expected at first, and sediment loads in succeeding years would diminish. In the absence of further movement, however, the creek has shown the ability to rapidly approach pre-slide conditions.

Sediments deposited in the irrigation network are inorganic clays and silts, of which 50 percent or more was clay. If the material were deposited on the farmland in sufficient quantity, it could reduce infiltration of irrigation water and result in crop damage. Observations in 1975 and 1976 reported that accumulated sediment 1/8 inch thick resulted in reduced infiltration rates. Based upon the Utah State University sediment sampling data, approximately 3,300 tons of sediment passed the Parshall flume (Sampling Station No. 2) during the 1976 irrigation season. Assuming all this sediment was uniformly deposited on the approximate 6,000 irrigated acres -- an insignificant buildup of only .004 inch per year would occur. At this rate it would take about 35 years to accumulate 1/8 inch of sediment. Actually, a large percent will settle out in canals and head ditches. Under these conditions normal tillage practices will keep the soils open, maintaining existing infiltration rates. Assuming all the sediment would be deposited on 10 percent of the land, a buildup of only .04 inch per year would accumulate. Sediment concentration would have to increase

many times over the average 1976 concentration before notable problems with maintenance and reduced soil percolation rates arise.

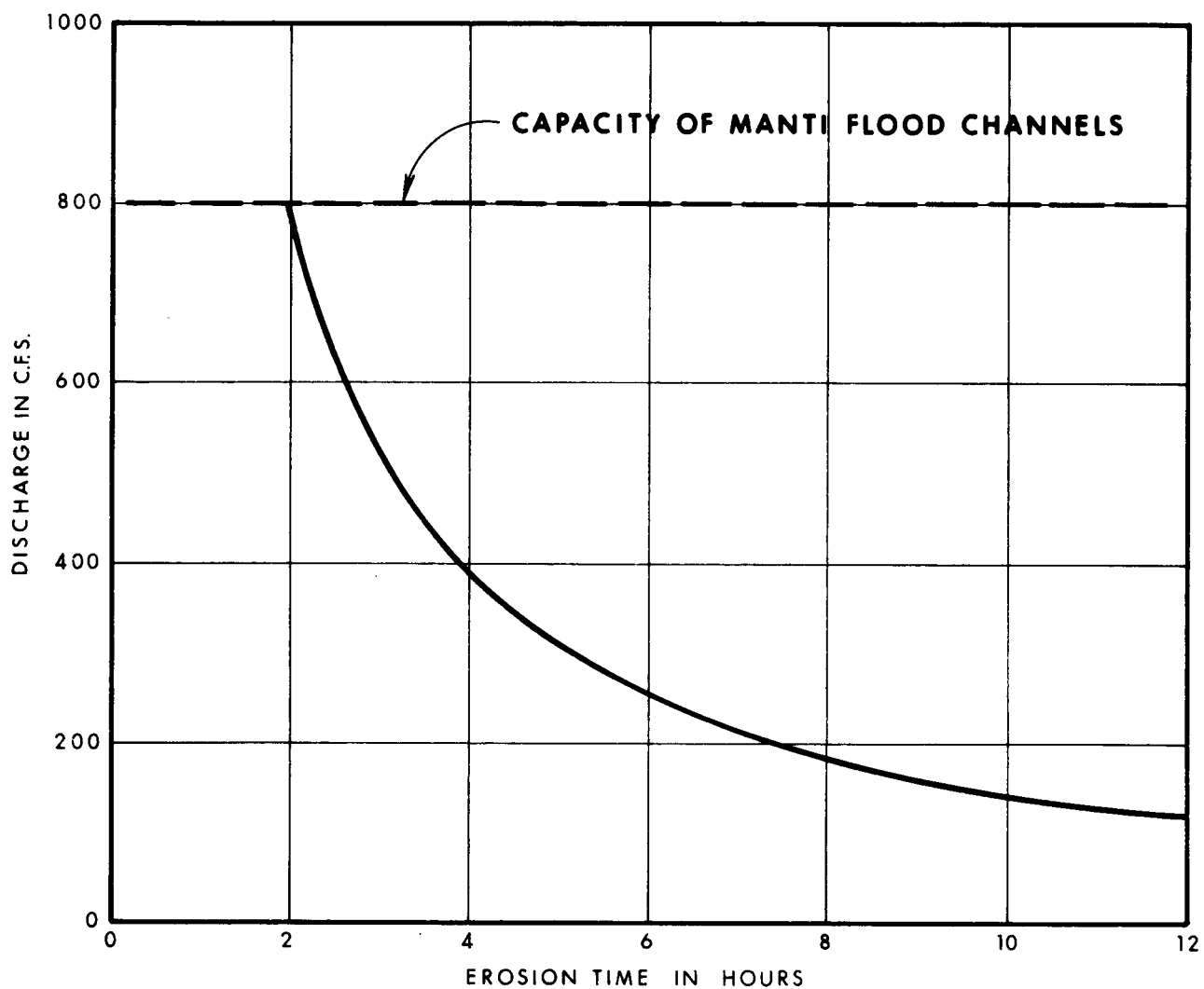


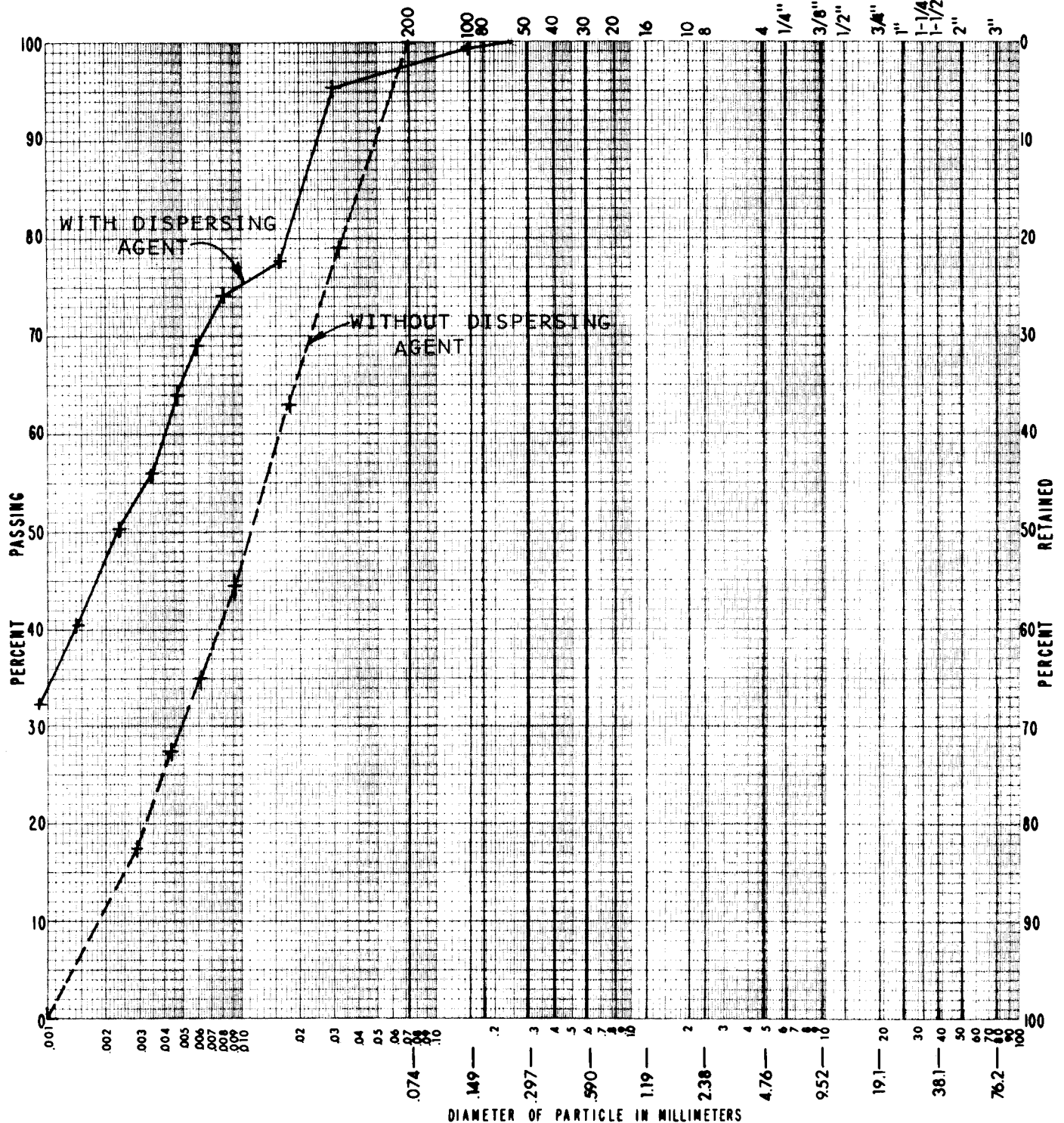
FIGURE III-1
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
**EROSION RATES OF
LANDFLOW DAM**

HYDROMETER ANALYSIS

SIEVE ANALYSIS

U.S. STANDARD SERIES

CLEAR SQUARE OPENINGS



CLAY (PLASTIC) TO SILT (NON-PLASTIC)

SAND

GRAVEL

FINE

MEDIUM

COARSE

FINE

COARSE

COBBLES

SAMPLED NEAR MIDDLE OF
LANDFLOW

FIGURE III-2
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
GRAIN SIZE ANALYSIS

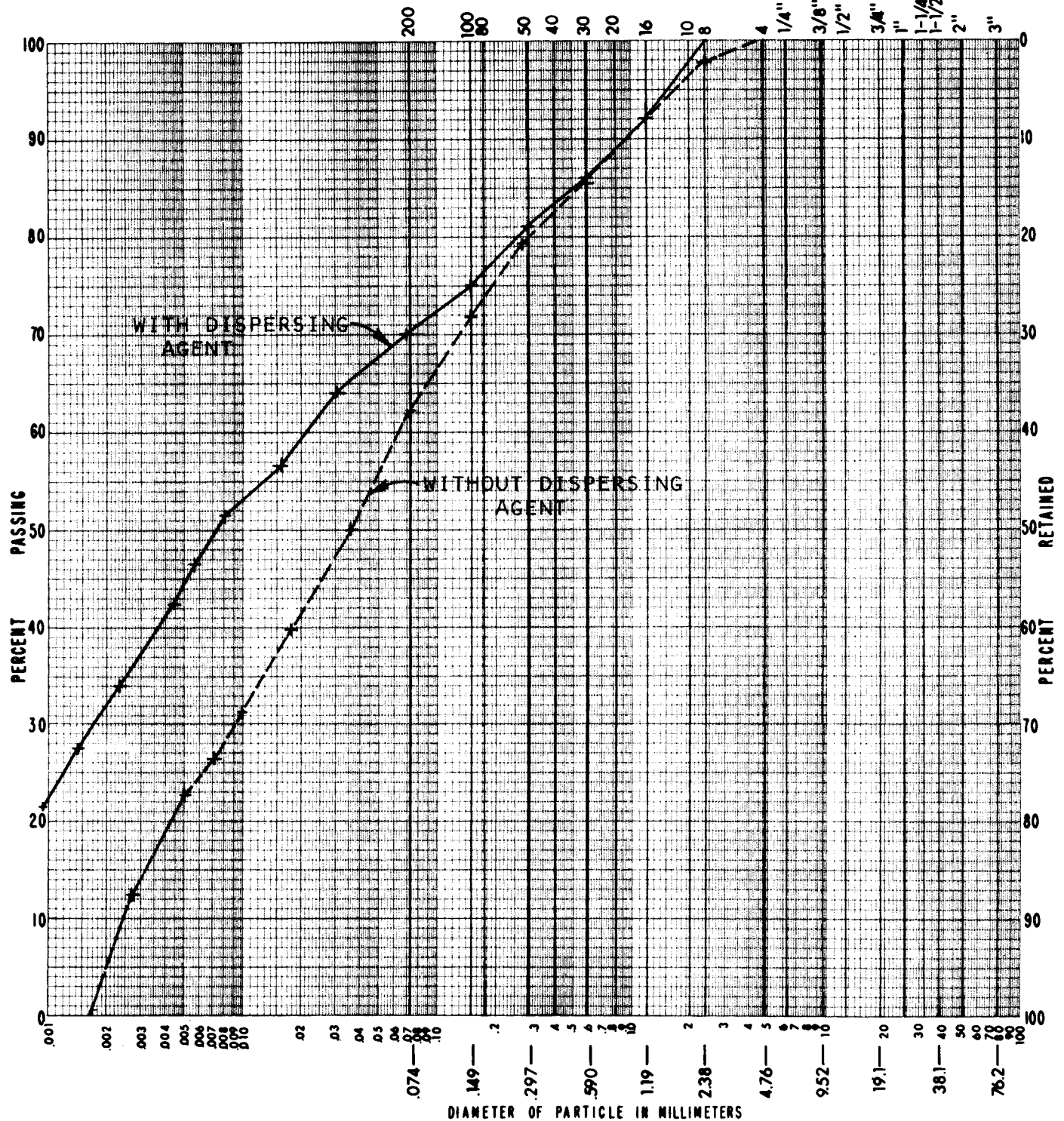


HYDROMETER ANALYSIS

SIEVE ANALYSIS

U.S. STANDARD SERIES

CLEAR SQUARE OPENINGS



CLAY (PLASTIC) TO SILT (NON-PLASTIC)

SAND

GRAVEL

COBBLES

FINE

MEDIUM

COARSE

FINE

COARSE

SAMPLED FROM MUDFLOW
NEAR CONRAD RESERVOIR

FIGURE III-3

U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
GRAIN SIZE ANALYSIS

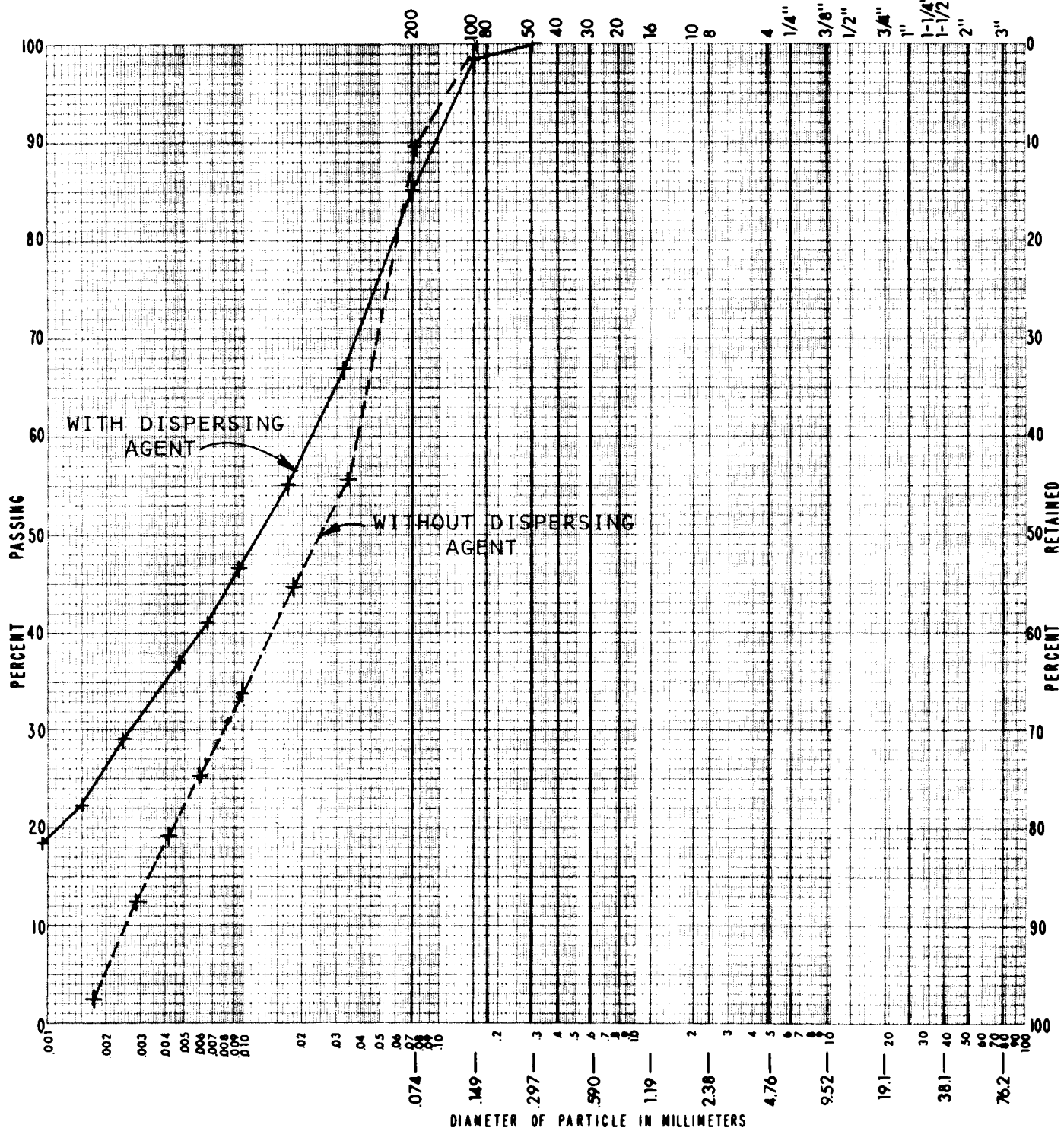


HYDROMETER ANALYSIS

SIEVE ANALYSIS

U.S. STANDARD SERIES

CLEAR SQUARE OPENINGS



CLAY (PLASTIC) TO SILT (NON-PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

SAMPLED
AT TOE OF LANDFLOW

FIGURE III-4
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
GRAIN SIZE ANALYSIS

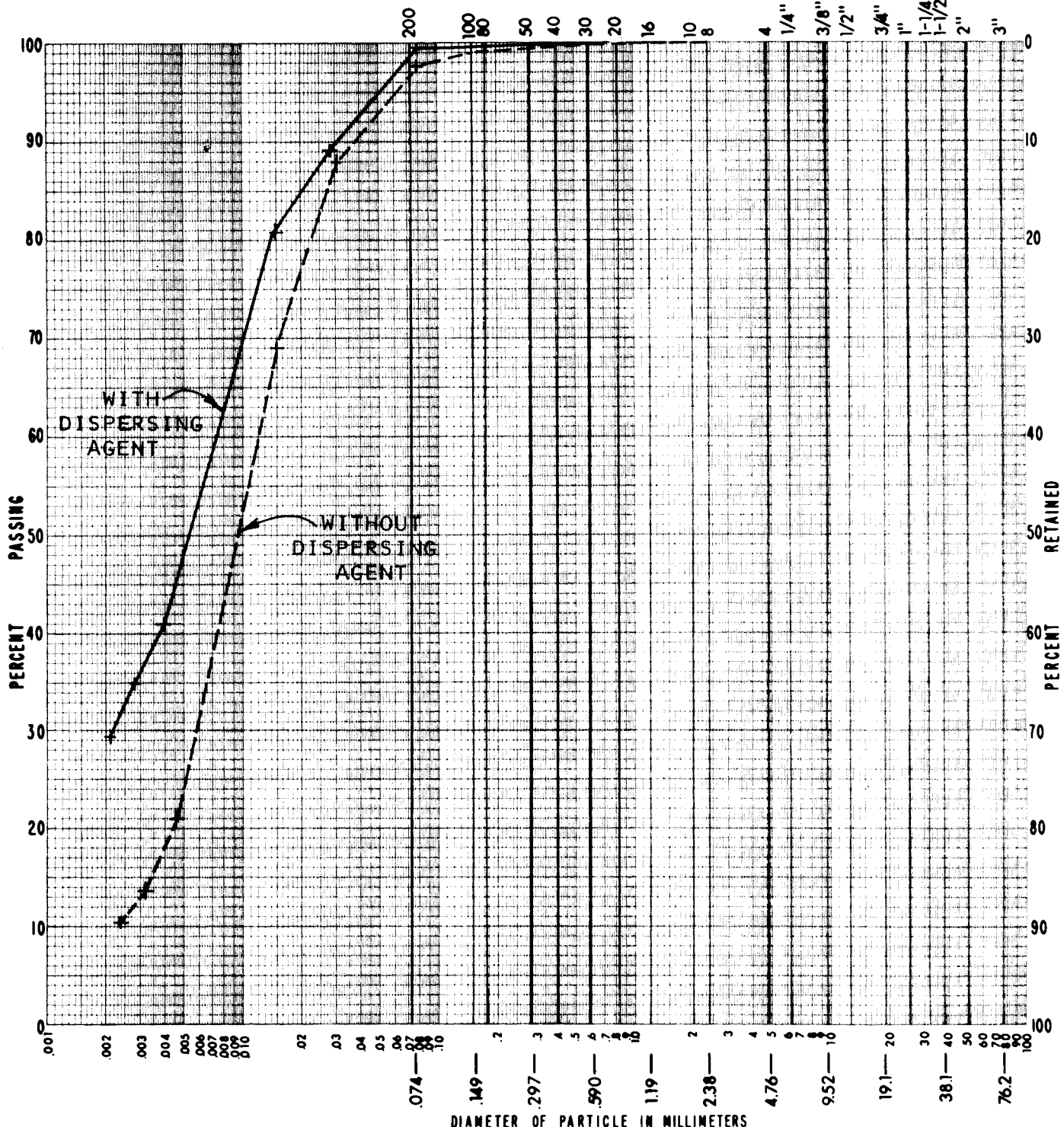


HYDROMETER ANALYSIS

SIEVE ANALYSIS

U.S. STANDARD SERIES

CLEAR SQUARE OPENINGS



CLAY (PLASTIC) TO SILT (NON-PLASTIC)

SAND

GRAVEL

COBBLES

FINE

MEDIUM

COARSE

FINE

COARSE

SAMPLED FROM DITCH BANK NEAR
MARVIN MILLER PROPERTY

FIGURE III-5
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
GRAIN SIZE ANALYSIS

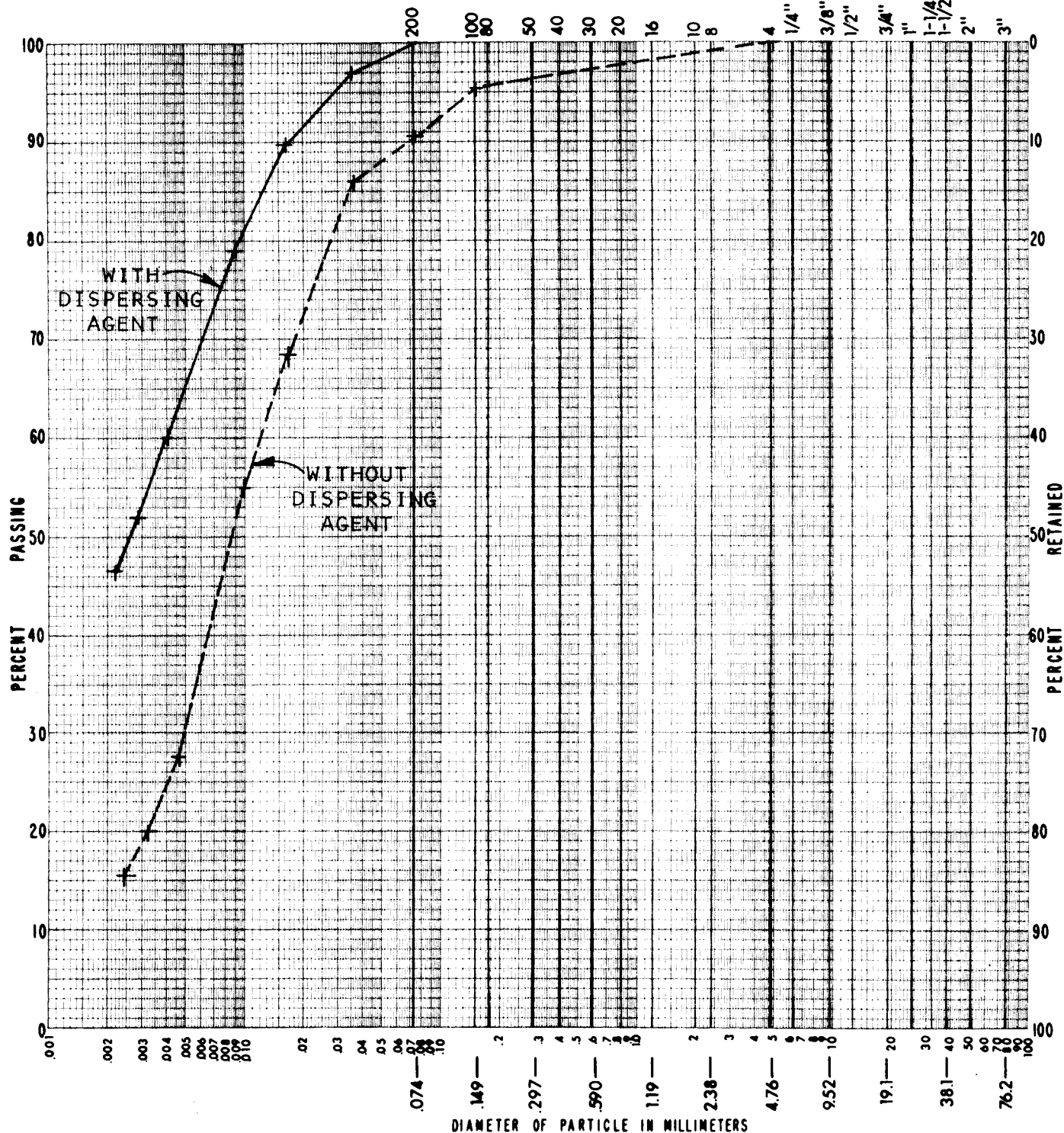


HYDROMETER ANALYSIS

SIEVE ANALYSIS

U.S. STANDARD SERIES

CLEAR SQUARE OPENINGS



CLAY (PLASTIC) TO SILT (NON-PLASTIC)

SAND

GRAVEL

COBBLES

FINE

MEDIUM

COARSE

FINE

COARSE

SAMPLED FROM SETTLING BASIN
MERRIL COX PROPERTY

FIGURE III-6
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
GRAIN SIZE ANALYSIS



Chapter 4

ALTERNATIVE COURSES OF ACTION



CHAPTER 4

ALTERNATIVE COURSES OF ACTION

GENERAL

Nine alternatives were developed as possible solutions to reduce the effects of the Cottonwood landflow. The conceptual alternatives listed below were identified by the Forest Service as a result of previous study, and by CH2M HILL during the course of this study. See Figure I-2 showing locations of alternatives.

- Alternative 1. Bypass Pipeline Around the Toe:
Divert Manti Creek around toe of landflow.
- Alternative 2. Construct a Debris Dam on Manti Creek:

Debris settling basin on Manti Creek near the mouth of Manti Creek.
- Alternative 3. Construct a Debris Dam on Cottonwood Creek:

Debris settling basin on Cottonwood Creek near Conrad Reservoir.
- Alternative 4. Stabilize Manti Creek:

Place erosion protection in Manti Creek along the toe of the landflow.
- Alternative 5. Divert Water From the Head of the Landflow:

Divert the headwaters of Cottonwood Creek around the landflow.
- Alternative 6. Divert Cottonwood Creek:

Divert Cottonwood Creek around the mudflow and Conrad Reservoir.

- Alternative 7. Do Nothing:
Use no structural measures.
- Alternative 8. Treatment Plant:
Chemically treat Manti Creek near the mouth of Manti Canyon.
- Alternative 9. Polymer Treatment:
Add polymers to Manti Creek, upstream of the existing debris dam, using the reservoir as a settling basin.

FEASIBILITY STUDY

The alternatives were evaluated according to engineering considerations, environmental impact, and costs. The evaluation was conducted in two cycles. After available data had been received and field investigations completed, each alternative was evaluated with respect to the following criteria:

- Its effectiveness to reduce sediment load in Manti Creek
- Engineering feasibility
- Environmental constraints
- Estimated cost

The cycle one evaluation concluded with Alternatives 3, 5 and 8 being dropped from further consideration due to either unsuitable engineering conditions, or their ineffectiveness in reducing sediments. Their effect upon physical or natural environments was insignificant and was not a factor in their elimination. A summary of the reasons for eliminating these three alternatives follows:

Alternative 3: Construct a Debris Dam on Cottonwood Creek

- There were no suitable dam sites located on Cottonwood Creek. The old Conrad Reservoir area was considered as a candidate site but rejected since the site could only be used if extensive work were done to remove existing embankments (considered unsafe) and accumulated silt in the reservoir area.
- Alternative 6 would accomplish the same objective as this alternative; both would reduce sediments in Cottonwood Creek.

Alternative 5: Divert Water From the Head of the Landflow

- Access of equipment above the head of the landflow would be difficult.
- Very little streamflow would be diverted.
- Very little effect on sediment.
- Diverting water to another drainage basin could possibly reactivate old landslides.
- Alternative 6 accomplishes the same objectives.

Alternative 8: Water Treatment Plant

- Treatment would require a flocculation - coagulation process which would be complex and could be costly to construct and maintain.

- Land requirements for the treatment plant are sizable and would make siting the facility difficult.
- To process more than 100 million gallons needed daily to supply spring irrigation requirements, the treatment plant would have to be comparable to a facility required for a large metropolitan area. The costs would be prohibitive for a small community.

Following the cycle one analysis, the remaining alternatives were further developed, refined, and evaluated. The cycle two evaluation included developing preliminary design layouts for each of the six remaining alternatives. Alternatives have not been evaluated with respect to reducing the potential of the landflow damming Manti Creek and flooding the City of Manti. As discussed in Chapter 3, the possibility of a damming and flooding sequence is not considered a threat to the City of Manti.

ALTERNATIVE DESCRIPTIONS

Alternative 1: Bypass Pipeline Around the Toe

Alternative 1 proposes to carry Manti Creek around the toe of Cottonwood landflow through a pipe parallel to, and north of, Manti Creek. The location of the pipeline is shown on Figure IV-1.

This pipeline bypass eliminates most of the sediment derived from the toe of the landflow since it separates the creek from the toe. To the extent that the toe provides sediment, this would reduce sediment in Manti Creek except in very large floods (greater than the 100 year flood).

The bypass has been sized to pass 860 cubic feet per second (cfs), the estimated flow of the 100 year flood, at the point of diversion.

The bypass alternative has three main elements:

- Intake-diversion structure to divert Manti Creek into the pipeline. See Figure IV-2.
- A 66-inch diameter pipeline around the toe. See Figure IV-1.
- A flip bucket-plunge pool energy dissipator at the downstream end. See Figure IV-3.

The in-take diversion structure is a diversion dam with a side-channel inlet to the pipe. Flows up to 860 cfs go into the side-channel inlet and down the pipe. At greater stream flows the diversion structure overtops with a portion of the flow going down Manti Creek and a portion flowing through the pipeline.

The 66-inch diameter pipeline would be buried at shallow depths to protect it against freezing and damage by vehicles and gunfire. Welded steel pipe is the preferred pipe type. Steel pipe is easy to install; in moderate thicknesses it has the necessary pressure range. High water velocities combined with some sediment requires an erosion-resistant pipe. Steel with an interior vinyl paint system is probably the most erosion-resistant material. A steel pipe can also tolerate more movement without leakage than other types of pipe.

The energy dissipator is a flip bucket with a plunge pool. A concrete, jump-type stilling basin could also be used, but

would be more expensive. The plunge pool is needed to minimize scouring of the creek channel which could, if unchecked, lead to local slope failures.

Alternative 2: Construct a Debris Dam on Manti Creek

Alternative 2 would reduce water velocity in Manti Creek and allow some of the suspended material to settle. This would reduce the amount of sediment in irrigation water used from the creek below such a debris dam.

Site investigations indicated the best location for a debris dam would be in the lower canyon either at the existing debris dam site or a short distance upstream. These sites allow greater reservoir capacity than the site about 1 mile upstream which was previously investigated. (Reference 6) See Figure IV-4.

Site Conditions

Foundation conditions should be similar to those reported for the more upstream site (Reference 6): several feet of rocky slope wash on each abutment with reworked slope wash and silty, gravelly, and cobbly alluvium. These materials are quite permeable.

A large reservoir could start landslides by saturating the toes of the reservoir slopes. The entire Manti Canyon area is highly susceptible to landsliding.

There does not appear to be any clayey (highly impermeable soil) for dam construction in the area. Clayey soils are desirable for the dam core and a blanket upstream of the dam to limit underseepage to safe levels. However, a safe dam can be constructed with the available soils even though the soil properties are not ideal.

Considering the poor foundation conditions, potential instability of reservoir slopes, less than ideal soils for construction, and previous geotechnical recommendations (Reference 6), the dam should be kept small -- impounding water less than about 40 feet deep.

Detailed field explorations and a drilling program are necessary for design and to determine the feasibility of constructing a dam of any significant height.

The earth debris dam, illustrated by Figures IV-4 and IV-5, creates a reservoir of 175 acre-feet with a surface area of 8.7 acres at normal water surface. The dam contains approximately 53,000 cubic yards of earth fill.

A 30-inch diameter, low-level outlet is provided with an upstream slide gate. The outlet could empty the reservoir in the event of an emergency.

A single, concrete chute spillway is located on the left abutment. The spillway can pass a flood flow of 6,000 cfs, the Probable Maximum Flood assumed for this report.

Sediment must be removed periodically from the reservoir. Based on sediment removal when the reservoir is half filled with sediment and an annual sediment load of 10 to 30 acre-feet per year, sediment must be removed every 3 to 8 years.

Alternative 4: Stabilize Manti Creek

This alternative would reduce erosion at the toe of the landflow, thus reducing sediment load in Manti Creek.

Stabilizing the creek channel is done by placing erosion protection in Manti Creek along the toe of the landflow. The channel would be re-aligned and excavated to a uniform cross section providing better flow conditions for Manti Creek. The steep portion of the creek bottom near the western toe of the landflow would be flattened as shown in Figure IV-6. This 25 percent gradient would reduce velocities and provide a more stable channel bottom than the present over-steepened section.

The Manti Creek channel would be excavated to a trapezoidal cross section and lined with riprap. The riprap has been sized so that the rock will not move for flows of less than 860 cfs. In steeper sections with gradients greater than 0.10, the maximum size riprap required is about 9 feet in diameter. In flatter sections with gradients less than 0.10, the maximum size is about 4.5 feet in diameter. Typical cross sections of the channel stabilization are shown in Figure IV-7.

Alternative 6: Divert Cottonwood Creek

This alternative would reduce the sediment load in Cottonwood Creek by eliminating the mudflow and Conrad Reservoir as sources of sediment. The mudflow and Conrad Reservoir have been reported as the major sources of sediment in Cottonwood Creek, (Reference 4). Streamflow in the Slide Fork of Cottonwood Creek would be diverted around the mudflow into the Burnt Hill Fork as shown in Figure II-1. Streamflow in the Burnt Hill Fork would flow into Cottonwood Creek and then be diverted around Conrad Reservoir and back into the existing channel.

This alternative consists of constructing two diversion structures on Cottonwood Creek: one on the Slide Fork above the mudflow and one on Cottonwood Creek above the Conrad Reservoir. The diversion structures and canal have been sized so that little erosion is expected for flows less than 20 cfs. Moderate erosion of the canal is expected during the 100 year flood. The stilling basin is a riprap-lined plunge pool designed for the 100 year flood. The 100 year flood (350 cfs) was determined using the rational method. Details of the diversion structure, canal, and stilling basin are shown on Figures IV-8 and IV-9.

Alternative 7: Do Nothing

This alternative means taking no corrective structural action to mitigate the effects of the Cottonwood landflow.

Alternative 9: Polymer Treatment

This alternative reduces sediment concentrations on Manti Creek by introducing a polymer coagulant in Manti Creek and utilizing the existing debris basin as a settling basin.

Polymers are normally used as coagulants in water treatment plants or wastewater treatment plants. Polymers have also been used as coagulants to:

- Remove fines from surface runoff on barren hillsides.
- Treat washwater from washing operations in sand and gravel pits.
- Treat other sediment-laden streams.

Polymers would be introduced in Manti Creek upstream of the existing debris basin. The polymer considered, M573C produced by American Cyanamid Company, is a non-toxic, liquid, cationic polymer. This particular polymer is very dispersive in water. Thirty minutes of mixing in the turbulent flow of Manti Creek is expected to completely mix the coagulant.

The polymer dosage is dependent on sediment concentration and streamflow, with estimated dosage rates ranging from 1 to 10 mg/l. Sediment concentration and streamflow would have to be determined at the point of discharge. Streamflow could be determined with a gauging station or Parshall flume but sediment concentration would have to be a visual, qualitative determination.

An operator would have to be trained to determine dosage requirements. A trial and error procedure would be used until the operator was familiar with the relationship between streamflow, sediment concentration, and dosage requirements.

Sediments settled by polymers form a relatively dense sediment, but not the gelatinous sludge typical of alum treatment. Sediments deposited in the existing debris basin could be dried and excavated using conventional earth-moving equipment. Material excavated from the basin could be used for road surfacing, structural fill or waste fill depending on the amount of clay and silt sized material.

ALTERNATIVE EVALUATIONS

Each of the alternatives were evaluated with respect to engineering and environmental considerations.

The engineering considerations used in the evaluation include level of performance, effect on the stability of existing slopes, duration and estimated cost of construction, and annual maintenance costs. The annual equivalent cost of all alternatives was computed to allow comparisons, taking into account first cost, interest cost, operation and maintenance cost, and life of project (See Appendix C, Table C-1). The estimates were based on the following assumptions:

- 20 year amortization at 6-3/8 percent interest
- Land cost - not included
- Structure life of 40 years
- Annual maintenance costs include an allotment for cleaning irrigation systems.

The environmental evaluation included an analysis of the qualitative and quantitative environmental impacts. Each alternative was evaluated as it affected seven environmental parameters: 1) Water Quality 2) Fisheries 3) Plant and Animal Communities 4) Recreation 5) Community Utilities and Facilities 6) Archaeological and Historical Value and 7) the Sensory Environment.

The environmental evaluation identified features of each alternative which would either improve or destroy the environment, as well as those impacts which would be temporary or permanent. Remedial measures that would minimize negative effects are suggested where appropriate.

The environmental evaluation does not include a discussion of the alternatives' ability to prevent slide-related flooding or their effects upon irrigated cropland. The

potential for the Cottonwood landflow to cause damaging flooding was dismissed as discussed in Chapter 3.

The effects of sediment on irrigated cropland could not be evaluated because there is insufficient data describing the sediment cycle in Manti Creek, the landflow's contribution to the total sediment load in Manti Creek, and the relationship of crop production to precipitation, irrigation, and sediment buildup. Efforts by the Soil Conservation Service (SCS) and Utah State University to determine the relationship of sediment buildup and potential crop damage were abandoned in the area when there was no measurable sediment buildup on the farmlands in 1976. The results of that study were to be heavily relied upon as data input for this study. Without this data and other critical information, the effects upon croplands could not be determined.

ALTERNATIVE 1 -- BYPASS PIPELINE

Engineering Considerations

The bypass pipeline diverts flows less than 860 cfs (equivalent to the 100 year flood) around the toe of the landflow, eliminating it as a source of sediment in most streamflow conditions.

Eliminating streamflow in the area of the slide toe would greatly reduce downcutting and erosion of the streambed. Erosion of the toe could lead to continued or increased slide movement. Cottonwood Creek is presently being diverted from its natural course into Yearns Reservoir. The intake to the pipeline has been located assuming this diversion will continue. This would benefit the bypass pipeline in two ways:

- During movement, the toe of the landflow was active below the old confluence of Cottonwood Creek and Manti Creek. Should the landflow move again, the intake to the pipeline could be destroyed.
- Yearns Reservoir performs as a settling basin for sediments in Cottonwood Creek.

The sediment load in Manti Creek will be reduced by eliminating the toe as a source of sediment; however, Cottonwood Creek and other tributaries of Manti Creek are also sources of sediment load in Manti Creek.

Because the pipeline route is across the "North Slide" (an old slide), the stability of the North Slide must be considered in evaluating this alternative. The North Slide has been described as ". . . incipiently unstable; . . . appears to be in a state of delicate equilibrium geologic-hydrologic factors such as earthquake and erosion or rising of the groundwater table, alone or combined, could upset the delicate natural equilibrium and trigger large scale movement of the North Slide" (Reference 6).

Long-term (post-construction) stability is a probable danger to the pipeline. The North Slide is apparently slowly creeping downhill (References 6 and 7). Such movements are common in relatively inactive landslides. This creep or massive movement of the North Slide could destroy the pipeline. Once the pipeline was broken, leakage could compound the problem by causing additional smaller-scale slides below the pipeline.

The long-term stability problem is:

- At best, continual monitoring and minor pipeline repairs as slow creep of the North Slide deforms the pipeline.
- At worst, the North Slide becomes active, destroying the pipeline and resulting in a complete loss of investment.

The report dealing with the stability of the North Slide, Reference 6, states, "It is recommended that a bypass pipeline not be considered as a viable permanent solution for mitigating sedimentation erosion and landslide problems on Manti Creek."

Construction of the bypass pipeline is expected to take from 6 to 12 months. Streamflow would have to be diverted while constructing the intake-diversion structure and the energy dissipator. Total estimated cost of construction is \$1,249,000.

Maintenance requirements would consist mainly of yearly cleaning of the inlet structure and pipeline. Debris and trash would have to be cleaned from the inlet structure to assure proper operation. This maintenance would be best performed in early Spring prior to peak flows from snowmelt. Estimated annual maintenance costs are \$2,600. The annual equivalent cost is estimated at \$98,700.

Environmental Considerations

Plant and Animal Communities. This alternative would remove the principal water source for vegetation growing along a 3,000 foot section of Manti Creek. Overall, this alternative has the greatest impact of any option upon vegetation and

animal communities. The primary plant communities are located at the east and west end of the slide toe; Manti Creek through the middle stretch of the slide toe does not support a plant community.

Vegetation growing within 50 feet of the streambank, involving approximately 150,000 square feet, would be lost if this alternative were implemented. Just above the toe of the landflow is an area known as the "The Cottonwoods." It consists of about 75 cottonwoods that cover an area of about 4 acres. Also included are willows, redosier dogwood, river birch, and wild rose. Although some of this area has already been disturbed or buried by the slide, the total community would be killed if this alternative were implemented. Along Manti Creek, 600 feet below the landflow, the stream channel levels off. Although no unique plant species occur, there is a viable strand of about 30 narrowleaf cottonwood trees over 50 years old. This vegetation would also be lost as a result of the alternative. Mixed white and douglas fir trees on the north slope of the stream are not dependent on water from the creek and would not be affected by the diversion. Some of the more attractive and striking tree growth occurs in this last area.

Pipeline construction will involve a corridor about 5,400 feet long and 20 feet wide involving 2.5 acres of land. Pipeline excavation during construction will require removal of overlying vegetation. Though the pipeline would be routed on the more sparsely vegetated north slope, plants are slow to re-establish themselves on the north side. The pipeline corridor would then be apparent for a long period of time, even with efforts to replant since tree growth is slow.

There were no animals along this stretch that would be significantly affected by the diversion. The animal population has already been disrupted by the landflow, and it is unlikely that further stream diversion will have any major impact on the remaining surrounding populations.

Several options could be considered in the design of this alternative to minimize the impact upon plant communities: Rather than divert the entire streamflow up to the 100 year flood, maintain a minimum flow in Manti Creek. Continued flow in the streambed would serve to sustain vegetation. Another option would be to alter the location of the pipeline -- for example, if the diversion pipeline were designed to start 600 feet below the east flank and extend only about 600 feet below the west flank of the slide toe, destroying the primary vegetation communities could be avoided.

Fishery. This alternative would destroy all the aquatic habitat in the slide toe reach of Manti Creek. Though this reach has demonstrated it can support fish life (trout), its importance to the overall fishery in Manti Creek is limited. It is unlikely that reproduction would occur and its importance for recreational fishing is limited because of restricted accessibility.

The fishery in Yearns Reservoir would be affected by the continued diversion of Cottonwood Creek. Sediment deposits would eliminate food production and reduce oxygen supplies for fish in the area of deposition. Deposits would have to be cleaned frequently to prevent development of a delta.

In general, the habitat in the lower reach will support fish, however, the actual population is insignificant, the reach is unimportant to the health of the total fishery and

is unimportant to the fisherman. Therefore, unless the posture of the State of Utah's planting program could change to include the lower reach of Manti Creek, the effect of this alternative or any other alternative, upon the aquatic environment is not a significant issue.

If the State should change its posture regarding planting fish in the lower reaches of Manti Creek, this alternative would benefit a downstream aquatic environment to some degree by reducing sediment contributed by the toe of the slide. A variation of Alternative 1, allowing a fixed stream flow to remain in the slide toe reach would be worthy of consideration if lower reach fish plants were re-established. The resulting flow stabilization in the slide toe area could then help an aquatic habitat which would remain productive on a year-round basis. Improvement in substrata composition (reduction in percent composition of fines) would benefit benthic invertebrate populations in particular. Populations of fish and invertebrates in the area would be less susceptible to "washout" during high spring runoff than populations in unstabilized areas.

Water Quality. Alternative 1 would remove the streamflow from its natural streambed, transporting it in a pipe to a point of discharge lower in the natural streambed below the landflow. This alternative would eliminate the entire landflow as a source of sediment by eliminating the toe as a source of sediment and using Yearns Reservoir to settle out sediment in Cottonwood Creek. However, periodic cleaning in Yearns Reservoir would be required to eliminate excess sediment buildup.

Assuming the landflow is the primary source of clay size materials, this alternative would be the most effective in their removal from Manti Creek.

Recreation. The major recreational pursuits in the canyon, fishing, hunting, hiking, camping and winter sports, would not be significantly disturbed by this project. A popular fishing spot in a stretch of Manti Creek east of the confluence of Manti and Cottonwood Creeks, would be eliminated by the upstream diversion. Many reaches of Manti Creek are similar in quality, but with respect to accessibility, this section of stream is very good. Almost no fishing occurs downstream from this point since there are no fish and the area is hard to reach.

Some congestion on Forest Service Road 50045 may occur periodically, resulting from a mix of construction equipment and recreation traffic, but not enough to close the road.

Construction of this project would result in no permanent or temporary disturbance to established recreational facilities in the canyon.

Sensory Environment. Alternative 1 could potentially have the greatest adverse visual effect of all the options. The most severe impact would be the death of vegetation adjacent to the diverted section of Manti Creek. Some filling in by species not dependent upon the stream may occur in the future. The absence of the stream in its natural stream bed would also have some negative visual effects.

Alternative 1 would not cause any long term elevation in noise levels. Construction noise would not significantly disturb developed areas or recreational activity. Increased heavy truck traffic along the access road from Manti to the canyon may cause some temporary disturbance to residents along the road. The pipeline would be close to a principle deer-migration but would have no effect on their movement following construction, and a limited effect during construction.

Archaeological and Historical Value. Only one site of any archaeological and historical significance on the north slope of the canyon was found after earlier surveys -- a small rock structure. The proposed pipeline would not disturb this site.

If Alternative 1 were selected, a detailed archaeological reconnaissance of the pipeline route would have to be conducted prior to construction. Any findings at that time could be salvaged. During construction an on-site investigation could be made by a professional archaeologist.

Community Utilities and Facilities. The pipeline is expected to produce some measurable reductions in stream sedimentation. The net effect should result in lower level maintenance requirements (less frequent sediment clean out) for the irrigation canals, powerhouse diversion canal, and existing debris basin.

ALTERNATIVE 2 -- DEBRIS DAM ON MANTI CREEK

Engineering Considerations

Debris dam sites were studied in Manti Canyon below the USGS gauging station. Above the gauging station the stream gradient and canyon walls were too steep to provide any significant storage capacity. The most favorable dam locations were considered to be below the site investigated in the IECO report, Reference 6, for two reasons: 1) the broader valley further down the canyon offers greater storage capacity, and 2) there appear to be fewer inactive landslides further down the canyon and less chance of disturbing old landslides.

Locating the debris basin near the mouth of Manti Canyon will affect sediment derived from the landflow and from areas above

and below it. Only sediments now carried by the lower powerhouse canal would be unaffected; the debris basin would be located below the intake to the canal and would not affect sediments in the canal.

Settling characteristics of the proposed debris basin under varying streamflow conditions are shown in Table IV-1. These calculations theoretically indicate that with normal peak streamflow conditions (100-200 cfs), only particles larger than silt size (.02 mm) would settle out. Referring to Figures III-5 and III-6, about 70 percent of the sediment sampled from the cropland was smaller than .02 mm. This indicates the debris basin would be ineffective in reducing these sediments.

The settling of suspended sediment is primarily a function of sediment size, reservoir surface area and detention time. To remove particles larger than .008 mm at streamflows of 100 cfs, a reservoir surface area of 20 acres is required. To remove .008 mm particles at a streamflow of 800 cfs, 155 acres is required. Physical characteristics and geologic conditions in Manti Canyon prevent the construction of a debris dam with these reservoir surface areas. Therefore, the proposed debris dam would not be able to remove all clay and silt size particles (.008 mm) for flows greater than 100 cfs.

The settling characteristics of the existing debris basin compared to the theoretical effectiveness of the proposed debris dam show the proposed dam would remove 42 percent more sediment at a streamflow of 100 cfs, but only 25 percent more at streamflows near 800 cfs. Therefore, during periods of peak runoff the proposed debris basin would be slightly more effective than the existing debris basin.

TABLE IV-1
SETTLING CHARACTERISTICS OF THE DEBRIS BASIN

Q Cubic Feet/ Sec. (cfs)	Q Gallons Per Day (gpd)	A Square Feet (sf)	Q/A (gpd/sf)	Detention Time (hrs)	Theoretical Particle Size (millimeters)
100	6.5×10^7	3.8×10^5	171	21.2	.017
200	1.3×10^8	3.8×10^5	341	10.6	.020
400	2.6×10^8	3.8×10^5	682	5.3	.030
800	5.2×10^8	3.8×10^5	1,364	2.7	.040

The foundation conditions in Manti Canyon are poor. Detailed studies may show that safe dam construction will be very expensive at sites in Manti Canyon.

Construction of the debris dam is expected to take from 6 to 12 months to complete. Manti Creek would have to be diverted to maintain irrigation demands and prevent increased sediment load due to construction activities.

Normal maintenance of the debris basin would require removing sediment every 3 to 8 years. An annual estimated maintenance cost is about \$59,200, assuming an average annual accumulation of 24,000 cubic yards of sediment. The total cost of constructing the debris basin is estimated at \$740,000. The annual equivalent cost of Alternative 2 is \$118,800.

Environmental Considerations

Plant and Animal Community. Vegetation in the vicinity of the dam site is pleasing and fairly uniform. Along the stream the vegetation consists of about 30 percent cottonwood 60 percent oak, and 10 percent juniper. There are a few areas where cottonwoods provide 20 percent cover, and sage close to 60 percent. The dam would inundate approximately nine acres of trees or large shrubs.

The animal communities described in Alternative 1 are also dominant in this lower stretch of Manti Creek. No unique animal plant species were found in this area.

Compared to the other options, this alternative is ranked third in degree of impact upon the plant and animal communities.

Fishery. This alternative would do little to adversely affect the existing aquatic environment in the lower reach

of Manti Creek. At the same time, however, it offers no improvement in the aquatic environment. Minor adverse effects could include reduced organism productivity and trout habitat in the impounded area. Periodic cleaning of the impoundment would have some minor intermittent effects downstream of the dam, such as increased levels of suspended and dissolved solids and nutrients.

Water Quality. The proposed debris dam could provide a settling time in the range of 20 hours during high flow periods of approximately 100 cfs. This would provide sufficient time to settle coarse to medium size silt (.030 - .020 mm), however, clay size sediments would not settle. Streamflows would have to be in the range of 15-20 cfs before the debris basin would begin to settle clay size material (.002 - .005 mm): during periods of high stream sedimentation (coinciding with high streamflow) the debris basin would be ineffective in removing the clay size particles from Manti Creek. During other periods the basin would function quite effectively but sediments would not typically be a problem during these periods unless slide movements were to reoccur.

Overall, this alternative serves to intercept not only the sediment originating from the landflow but most of Manti Canyon. Its ability to settle clay particles during period of high flows is a serious short coming.

Recreation. Alternative 2 is a structural solution, located furthest from centers of recreational activity in the canyon. This alternative would have no lasting adverse effects upon recreational pursuits or recreational facilities in the canyon. This alternative would cause some periodic traffic congestion along Forest Service Road 50045 but would not cause road closures.

Sensory Environment. The debris dam would assume a position of visual dominance in the "Lower Canyon Visual Unit."

It would fit in with the many other man-made features in this area. The dam would stretch across the canyon floor but its height of only 40 feet would still permit extended views up the canyon and its earth and rock face would blend with surroundings. Since Manti Creek is not a highly vivid, rushing stream in this area, the reservoir could add a refreshing visual feature to this part of the canyon. Inundation by the reservoir would not disturb any visually significant features nor diminish any topographic relief. The reservoir would remove some vegetation, but any adverse effects could be minimized by locating the dam in an area of relatively sparse vegetation.

Archaeological and Historical Value. Alternative 2 would be located in the central section of the canyon that has the most (though limited) archaeological potential. No known sites have been found in the vicinity of the dam site(s). As in Alternative 1, a detailed reconnaissance of the site prior to construction would be conducted and any findings would be tested and salvaged. A professional archaeologist would also be retained to examine excavations during construction.

Community Utilities and Facilities. The proposed debris basin would require relocating Forest Service Road 50045. The new alignment would be elevated slightly along the north slope of the canyon. While detours would be required during this relocation, perhaps resulting in some traffic congestion, no road closures are anticipated.

ALTERNATIVE 4 -- STABILIZE MANTI CREEK

Engineering Considerations

Channel stabilization would consist of armoring the Manti Creek channel along the toe of the landflow, thus reducing erosion and downcutting of the toe.

This would reduce erosion and the amount of sediment supplied by the toe of the landflow, but not sediments supplied by other sources such as Cottonwood Creek and other tributaries of Manti Creek. Reducing erosion at the toe of the landflow would stabilize the toe by reducing downcutting of the channel bottom.

One major disadvantage of channel stabilization is that if the slide were to continue to move at any rate, the channel bottom would be disrupted, displacing the riprap armor.

A stability analysis performed on the toe determined the effects of the groundwater and soil strength properties on the stability of the slope. Results of this analysis, performed on a cross section taken at the western toe of the slide, is shown in Figure II-1. This area was selected because of the steep, high banks. The model and results of the analysis are shown in Figures IV-10 to IV-12.

No subsurface exploration has been performed on the Cottonwood landflow. Therefore, the groundwater conditions within the slide mass had to be assumed. Three groundwater conditions were assumed to determine the effect on the toe stability (see Figures IV-10 to IV-12):

- Groundwater at the ground surface.
- Groundwater sloping at 3:1 (3 horizontal: 1 vertical) from Manti Creek.
- Groundwater sloping at 12:1 from Manti Creek.

No information is available to determine the strength properties of the landflow mass. Strength parameters were assumed equal to those samples tested in Drill Hole 2 of the IECO Interim Geotechnical Report (Reference 6). The strength parameters were varied to determine the soil properties required to maintain a stable slope using a factor of safety of 1.0.

Results of the stability analysis indicate:

- The stability of the toe is highly affected by groundwater fluctuation.
- The relatively shallow failure surface indicates bedrock does not control toe stability.
- Using strength parameters developed by IECO, the toe of the slide appears stable.

The armoring of the toe is estimated to take about 9 months to complete, assuming construction could be continued through the Winter months with only some delay during the peak runoff in May and June. The estimated cost of construction is \$2,000,000 with annual maintenance costs at \$5,000 for the first five years. A yearly inspection would need to be conducted each Summer following the spring freshets. Some

rock movement is expected in the first 5 years of operation as the channel bottom stabilizes. Yearly maintenance would take one week of clean up and replacement of riprap. After the channel bottom has stabilized maintenance is expected to be minimal. The annual equivalent cost of Alternative 4 is \$167,200.

Environmental Considerations

Plant and Animal Communities. Stabilizing the stream channel would disrupt the existing vegetation. This option, similar to Alternative 1, would affect some desirable tree stands at the upper and lower ends of the slide toe.

There would be no significant effect on the animal community, especially in the slide toe area where the population density was considered to have been very low after the slide movement.

This alternative would have a significant impact upon the vegetative community, second only to Alternative 1. The following suggestions are offered to minimize these effects: Limit stabilizing Manti Creek to the steeper grades of the creek and direct it toward improving the appearance of the terrain. Seed the barren toe of the landflow with a range forage species such as the wheat grasses.

Fishery. Serious consideration of this alternative assumes that the Cottonwood landflow has stopped and further disruption of the streambed will not occur. Although sediments would continue to flow into the area from upstream reaches, the effects of bank stabilization at the toe would reduce siltation from local bank erosion. These conditions would favor benthic insect populations and improved trout habitats in the vicinity of the slide and areas downstream.

Water Quality. Alternative 4, similar to Alternative 1, would eliminate the stream's natural ability to remove bed and bank material in the landflow toe area. Unlike Alternative 1, however, Cottonwood Creek would be returned to its natural stream channel, entering Manti Creek near the east flank of the landflow toe. Assuming Cottonwood Creek does not contribute significantly to sediment loads in Manti Creek, the differences between Alternative 1 and Alternative 4 may be minor.

Construction of Alternative 4 would directly involve almost 3,000 feet of streambed. Without precautionary measures construction itself could result in increased sediment concentrations during the period of construction.

Recreation. This alternative, similar to Alternative 2, would not significantly disrupt recreational activities or recreational facilities located in the canyon.

Sensory Environment. This alternative, more than any other, would improve the visual quality of the most devastated portion of the slide toe area. Construction would require removal of dead trees; ponded areas would be cleaned and returned to a free-flowing state. Visual appearance could be heightened by augmenting this alternative with some slope-grooming in the slide toe area, and re-vegetation.

Alternative 4 would cause no long term changes in ambient noise levels in the area. Construction noise would not disturb developed areas or recreational activities. The suggested site is sufficiently far from major deer migration routes to have no impact upon it, even if construction occurred during migration.

Archaeological and Historical Value. This alternative would have virtually no impact on archaeological or historical resources. The construction would take place in an area already totally disrupted by the landflow movement. No remnants have been observed, nor is it likely that any survived the movement. No special reconnaissance prior to, or during, construction would be required.

Community Utilities and Facilities. Alternative 4 would not cause any adverse impacts upon utilities or facilities during or after construction. The project would reduce stream sedimentation resulting in lower maintenance requirements for irrigation canals, the powerhouse diversion canal, and the existing debris basin.

ALTERNATIVE 6 -- DIVERT COTTONWOOD CREEK

Engineering Considerations

Diverting Cottonwood Creek around the mudflow and Conrad Reservoir would eliminate these as sources of sediment in Cottonwood Creek.

By reducing these major sources of sediment in Cottonwood Creek, the sediment load in Manti Creek would also be reduced. This does not affect sediment derived from the toe of the landflow or other sources in Manti Canyon.

The diversion structures are sized for the 100 year flood. During such large flows the structures may be filled with debris, resulting in overtopping the canal. Providing wasteways would prevent damage to the canal and hydraulic structures.

The diversion of Cottonwood Creek requires the least work of any of the alternatives except Alternatives 7 and 9. Construction of the diversion structures and pipe outlet is expected to take 3 to 6 months to complete and to cost about \$91,300.

Maintenance would require cleaning the two diversion structures and canal. Debris, trash and some sediment is expected to accumulate in the diversion structures and canal until vegetation is established on the hillside above the creek. Annual maintenance costs as estimated at \$15,400. The annual equivalent cost of Alternative 6 is \$22,400.

Environmental Considerations

Plant and Animal Communities. Since this alternative would divert water around Conrad Reservoir, it would dry it out. This would result in the death of 4 acres of willows and some dogwood and river birch plants. Over a period of about 15 to 20 years, the four- to five-acre area affected would gradually be occupied by aspen, followed by white fir, douglas fir, and spruce.

Fishery. Alternative 6 would benefit the aquatic biological resources in Cottonwood and Manti Creeks directly proportional to reduced sedimentation. In the judgment of the consultant, the total reduction in sediment could be relatively small. Since there are no fish in Cottonwood Creek, the net effect could be growth of a more vigorous benthic invertebrate population in that stream. Manti Creek would most probably only benefit in the short reach from the confluence to the barren slide toe area.

Water Quality. The mudflow near the head of the Cottonwood landflow is predominantly clayey material; the Slide Fork of Cottonwood Creek now flows through this mudflow. The proposed Slide Fork diversion would occur in a relatively flat segment of the stream's profile of the stream's headwaters; the contributing drainage area is small. The combination of these factors would result in a lower erosion potential since the area available for scouring is quite small. Next to the "Do Nothing" alternative, this option would reduce stream sediments in Manti Creek least.

Recreation. This alternative would have no significant or lasting effects upon recreational activities in Manti Canyon since the diversion is located away from established recreational facilities and most recreational pursuits. While the facility would be located in an excellent deer and elk habitat, a choice hunting area could be temporarily disturbed if construction coincided with the deer and elk hunting season.

Sensory Environment. This alternative would be located in the "Landflow Visual Unit" near the head of the slide. Tree cover and topography would preclude any long axial views of the project area.

Natural devastation caused by the landflow is the predominant image of the area; Alternative 6, consisting of low profile structures would be unassuming in this setting. The most adverse visual impact would be the death of the four-acre willow community.

The project would not cause any long term elevated noise levels. Construction noise would not reach developed areas, and only temporary disturbances to the animal community might result.

Archaeological and Historical Value. Alternative 6 would be located far from any known or potential archaeological or historical sites in the area. The alternative itself would render no harm to cultural remnants, but once again, similar to Alternatives 1 and 2, precautionary steps would be taken including a detailed site reconnaissance prior to construction.

Community Utilities and Facilities. This alternative would cause no adverse effects on community utilities and facilities in Manti Canyon. It would minimally reduce sediment loads in the lower reaches of Manti Creek. Therefore, maintenance levels required for the powerhouse diversion canal, irrigation canal, and debris basin would be similar to Alternative 7.

ALTERNATIVE 7 -- DO NOTHING

Engineering Considerations

This alternative consists of taking no corrective action to reduce the effects of the landflow.

"Maintenance" of this alternative would be similar to corrective measures taken during the last two years: monthly flushing of the lower powerhouse diversion canal and periodic cleaning of irrigation laterals and furrows during periods of peak sediment load in Manti Creek. Costs of this maintenance have been minimal. This maintenance should reduce as the landflow stabilizes and Manti Creek armors its channel, and as vegetation grows back in the disturbed areas of the landflow. The annual equivalent cost of Alternative 7 is \$16,000.

Environmental Considerations

Plant and Animal Communities. If nothing were done, plant and animal communities in the affected landflow area would, presumably, over a period of decades, reach a state of equilibrium and stability in the same manner as followed prehistoric slides in the region.

The east main branch of Cottonwood Creek would flow much as it now does resulting in no notable change in the surrounding aspen community. In the lower stretch where it has been partly inundated or impounded by the slide, much of the streamside vegetation will continue to die. Gradually a new watercourse would establish itself and the surrounding vegetation would attain a new equilibrium.

Along the stretches where the slope is nearly level, the characteristic streamside community dominated by cottonwoods with occasional river birch and dogwood should develop. This could also be expected following either Alternative 2 or 4. The animal communities have not been significantly affected by the landflow, so no major changes would be anticipated.

Fishery. If the movement of the landflow has virtually ceased, gradual improvement in aquatic habitats can be expected. For those areas adversely affected by siltation and erosion caused by the slide, improvement in aquatic biological resources can be anticipated. This improvement will continue until sedimentation in downstream areas become stabilized at new lower levels.

If movement of the landflow continues, heavy sediment loads can be expected during periods of high runoff. Degradation of aquatic habitats and resulting negative impacts on aquatic resources will result.

Water Quality. Assuming no corrective actions were taken in Manti Canyon, the water quality and concentrations of sediment in Manti Creek should approach pre-slide conditions. The stream has demonstrated the ability to respond quickly to changing conditions and attain a new level of equilibrium. The available data would indicate the stream is rapidly proceeding toward the pre-slide conditions.

Recreation. This alternative would have no effect upon recreational pursuits or recreation facilities in Manti Canyon.

Sensory Environment. This alternative would cause no visual change or changes in ambient noise levels in the canyon.

Archaeological and Historical Value. This alternative would have no impact upon archaeological or historical remnants.

Community Utilities and Facilities. Alternative 7 may require above normal maintenance for short time periods for the powerhouse diversion canal, irrigation laterals, and existing debris basin. The maintenance levels would be similar to the experiences during periods of high stream sedimentation in 1975 and 1976, involving frequent sediment removal. Maintenance levels will diminish successively each year to the point of pre-slide maintenance, assuming conditions affecting stream sedimentation do not change due to new slide movement.

ALTERNATIVE 9 -- POLYMER TREATMENT

Engineering Considerations

Polymer treatment consists of introducing a polymer coagulant into Manti Creek and using the existing debris basin as a settling basin.

The polymer, when applied in proper dosages, would settle out most of the clay and silt size particles resulting in better water quality than was observed before the landflow.

A field test would have to be performed to verify the particular polymer type and required dosages. Once these have been determined, an operator would have to be trained to apply the proper dosages to the stream.

A definite advantage of Alternative 9 is that treatment with polymers is not a continuous operation. Unlike other alternatives that affect sediment loads throughout the year, the polymers could be added only during those periods of peak sediment concentrations.

The debris basin would require annual cleaning. Depending on the amount of fines, the excavated material could be used for road surfacing or structural fill. If there are too many fines, the material would have to be wasted.

The total cost of implementing the polymer treatment alternatives is estimated at \$31,790. Annual maintenance costs for sediment removal are estimated at \$48,000 based on an average accumulation of sediment of 24,000 cubic yards. The annual cost of supplying and adding the polymer is estimated at \$38,750. The annual equivalent cost of this alternative is \$91,200.

Environmental Considerations

Plant and Animal Communities. Vegetation in the vicinity of the project site is pleasing and fairly uniform. Vegetation along the stream consists of about 30 percent cottonwood tree cover, 60 percent oak and 10 percent juniper. Alternative 9 would not require disturbing any existing vegetation.

A non-toxic chemical coagulant would be used in the treatment phase of this alternative. The coagulant would be applied in the stream above the existing debris dam. No damage to vegetation is anticipated as a result of infiltration of treated water seeping into the root zone.

The animal community in the vicinity of the proposed alternative includes an abundance of deer mice and pinion mice. The uinta and cliff chipmunk are also present. Livestock, primarily cattle, are also present in the area during the grazing season. Construction activity would be minor; it would not disturb the animal community. Consumption by the livestock or wildlife of the polymer-treated water should not harm the animals. Several varieties of non-toxic polymers are approved at concentrations up to 20 parts per million (ppm) in potable water by the Environmental Protection Agency (EPA). The proposed dosage would be 2-5 ppm, well below the approved limit.

Fishery. Alternative 9 would use approximately 2,000-3,000 feet in the lower reach of Manti Creek immediately above the existing debris basin as a polymer mixing zone. Results of fish bioassays, shown below, for a brand name non-toxic polymer indicate very low effects on fish if proposed dosages of 2-5 ppm are utilized.

FISH BIOASSAY RESULT*

<u>Specie</u>	<u>Survival Rate</u>	<u>Duration</u>	<u>Concentration</u>
Trout	50%	24 hours	38 mg/l
Trout	50%	96 hours	16 mg/l

* Source: American Cyanamid Company

Any adverse effects of this alternative upon the fishery is further diminished by the very small fish population in this reach of Manti Creek.

The alternative would offer no improvement in the aquatic environment in Manti Creek; improvements in water quality would only occur in the irrigation system, not in the natural stream.

Water Quality. Alternative 9 would provide for almost complete sediment removal. The existing debris basin "by itself" will settle gravels, sand size particles and most silt size materials (about .025 mm and larger at a streamflow of 100 cfs) during high streamflow conditions. The addition of polymer treatment would cause smaller silt size and clay size materials to coagulate and settle.

The polymers would be added to Manti Creek in concentrations between 2-5 ppm, well below the EPA-approved concentration of 20 ppm in potable water.

The residual effects of polymers in irrigation water and upon cropland would be insignificant.

The powerhouse diversion canal leaves Manti Creek above the debris basin, re-entering into the creek below the debris dam. Therefore, this flow would not be treated under this alternative. The effect of sediment concentrations in this untreated flow upon the irrigation system and cropland would be minor because the canal represents less than 10 percent of the total streamflow even during periods of high flow.

Alternative 9 would capture and treat sediment concentrations in Manti Creek originating from all of Manti Canyon. This alternative focuses upon canyon conditions that historically have prevailed and will continue to prevail.

Since landslides have occurred in the past and might occur in the future, this alternative provides a solution that addresses all conditions in the entire canyon that contribute to stream sedimentation rather than merely the effects of a single slide. Assuming reliable operation, this alternative would produce a relatively sediment-free discharge. Water quality in the irrigation canals would be superior to any levels experienced during the history of the Manti Irrigation Company.

Recreation. Alternative 9 would have no effect upon recreation pursuits or recreation facilities in Manti Canyon.

Sensory Environment. This alternative would cause no visual change or change in ambient noise levels in Manti Canyon.

Archaeological and Historical Value. This alternative would have no impact upon archaeological or historical remnants.

Community Utilities and Facilities. Alternative 9 would not cause any community utilities or facilities to be disturbed or relocated. This alternative does, however, significantly reduce sediment buildup in irrigation canals to minor levels. Under this condition the maintenance and removal of sediment would be even less than during pre-slide conditions.

The quality of water entering the powerhouse diversion canal would not be affected by this alternative. Sediment buildup and corresponding maintenance in the canal can still be expected to be high, particularly during periods of high streamflow. However, maintenance levels in the canal can be expected to diminish during future years to a point nearing pre-slide maintenance levels as sediment concentrations decrease.

SUMMARY ALTERNATIVE EVALUATION

A comparative summary of the six alternatives is offered in Table IV-2. This summary provides a concise method for comparing engineering considerations which affect each alternative, and the relative degree of positive or negative environmental impacts associated with each alternative.

Based upon the preceding evaluation, the alternatives have been ranked from most to least effective in four categories:

- ability to reduce stream sediments
- engineering considerations
- annual equivalent costs
- environmental impacts

Ability to reduce sediments in Manti Creek; number 1 being considered most effective:

Rank

- | | |
|---|---|
| 1 | Alternative 9 - Polymer Treatment |
| 2 | Alternative 1 - Bypass Pipeline |
| 3 | Alternative 4 - Stabilize Manti Creek |
| 4 | Alternative 2 - Debris Dam on Manti Creek |
| 5 | Alternative 6 - Divert Cottonwood Creek |
| 6 | Alternative 7 - Do Nothing |

Annual equivalent costs:

Rank

- | | |
|---|---------------------------|
| 1 | Alternative 7 - \$ 16,000 |
| 2 | Alternative 6 - 22,400 |
| 3 | Alternative 9 - 91,200 |
| 4 | Alternative 2 - 98,700 |
| 5 | Alternative 1 - 118,000 |
| 6 | Alternative 4 - 167,200 |

Major engineering considerations: (the No. 1 rank represents that alternative which has a combination of long-term reliability, ease of construction, and low maintenance and operation efforts. Successive ranks represent less desirable combinations of these criteria.)

Rank

- | | |
|---|---|
| 1 | Alternative 1 - Bypass Pipeline |
| 2 | Alternative 6 - Divert Cottonwood Creek |
| 3 | Alternative 4 - Stabilize Manti Creek |

- | | |
|---|--|
| 4 | Alternative 2 - Debris Dam on Manti Creek |
| 5 | Alternative 9 - Polymer Treatment |
| 6 | Alternative 7 - Do Nothing -- not applicable |

Impact upon the environment: (the alternatives are ranked from least to most adverse impact upon the environment. Their effect upon water quality is not included in this ranking.)

Rank

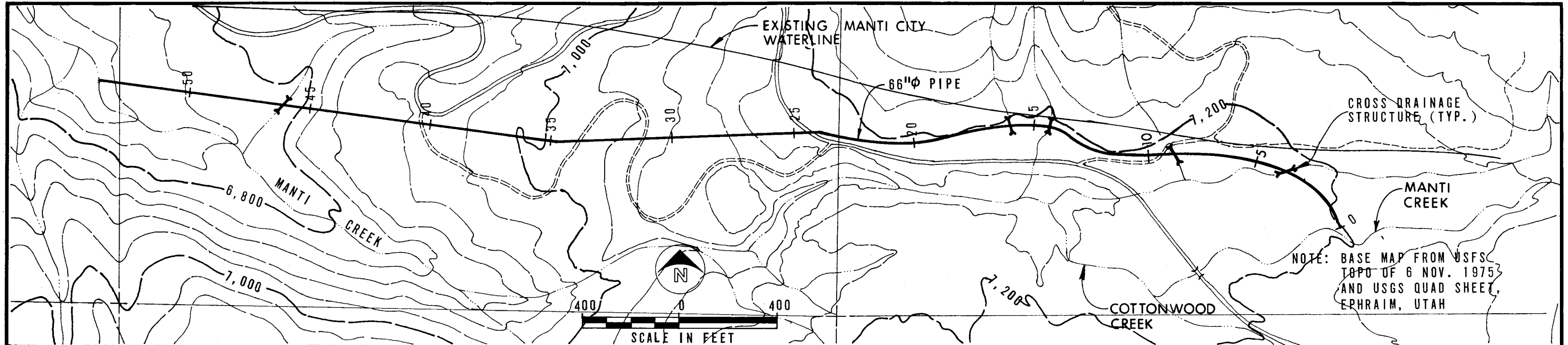
- | | |
|---|---|
| 1 | Alternative 7 - Do Nothing |
| 2 | Alternative 9 - Polymer Treatment |
| 3 | Alternative 6 - Divert Cottonwood Creek |
| 4 | Alternative 2 - Debris Dam on Manti Creek |
| 5 | Alternative 4 - Stabilize Manti Creek |
| 6 | Alternative 1 - Bypass Pipeline |

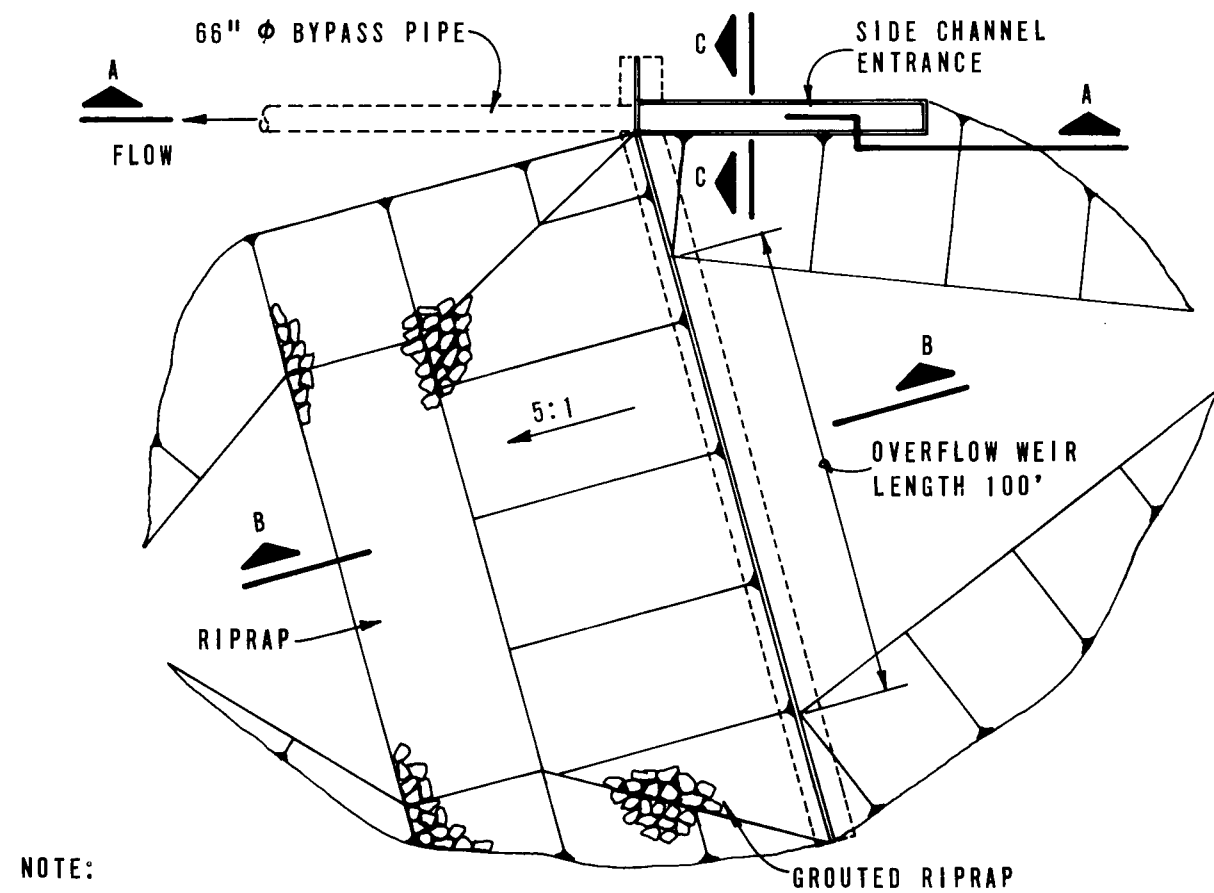
TABLE IV-2
COMPARATIVE SUMMARY MATRIX

ENVIRONMENTAL CONSIDERATIONS	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 4	ALTERNATIVE 6	ALTERNATIVE 7	ALTERNATIVE 9
PLANT AND ANIMAL COMMUNITY	Alternative 1 would have the greatest impact of the five alternatives upon the plant community. Significant tree stands at the east and west end of the slide toe would be killed. Animal population has already been significantly disrupted by the landflow and it is unlikely that this alternative would result in further degradation.	Alternative 2 would cause 9 acres to be inundated from which trees and large shrubs would be removed. The affects of this option upon the plant and animal community would only be moderate compared to other options.	Similar to Alternative 1, the alternative would destroy some desirable stand of trees at the east and west ends of the slide toe. Stabilizing the central part of the toe, however, may encourage or hasten revegetation in this area. No impacts upon the animal community are anticipated.	Approximately 4 acres of willow would be destroyed by this alternative. Impacts upon the animal community would be minor.	Plant and animal communities in the landflow area would, over a period of decades, reach a state of equilibrium and stability in much the same manner as in areas of prehistoric slides.	Alternative 9 would have very little impact on the plant and animal community. Non-toxic polymers would be used.
FISHERY	This alternative would destroy all aquatic habitat in the slide toe reach of Manti Creek. Assuming the State were to resume fish planting in the lower reach of Manti Creek. Alternative 1 would provide the most significant improvement to this aquatic environment.	This alternative would have no significant adverse impact upon the aquatic environment, however, it offers no improvement to that environment either.	This alternative would have no significant effects upon the fishery. The alternative would cause some improvement in downstream habitat.	This alternative would result in a more vigorous benthic population in Cottonwood Creek – no fish are present in the stream. The beneficial impacts in Manti Creek would only occur in a short stretch of stream below the confluence of Cottonwood Creek.	Improvement in the aquatic habitats in and below the slide area can not be expected until sediment transport in Manti Creek becomes stabilized at new lower levels.	There is very little fishery near the existing debris basin. The non-toxic polymer is not expected to affect the few fish in the reach of Manti Creek.
WATER QUALITY	Alternative 1 would be the most effective solution in eliminating the Cottonwood landflow as a potential source of sediment.	This alternative would intercept sediments originated from most of Manti Canyon. The debris basin, however, would only provide sufficient detention time to settle silt size particles or larger during peak runoff periods. the clay size particles would not be removed from the streamflow.	This alternative would eliminate the streams natural ability to remove bed and bank material from the slide toe area resulting in less stream sedimentation.	This alternative would have the lowest level of sediment removed in Manti Creek of the "build" alternative.	Sediment concentration would diminish each year as the stream approaches a state of equilibrium. Increased fluctuations in sedimentation would be noted, however, if the landflow resumed movement or stream discharge exceeded the previous year.	The polymer treatment affects all sediment in Manti Creek. If applied in proper dosages polymers are expected to settle out most of the clay and silt material.
ARCHAEOLOGICAL AND HISTORIC CONSIDERATIONS	A section of the pipeline would be located in a part of the canyon having some archaeological potential. No sites are known to exist in the path of the pipeline.	Alternative 2 would be located central to the portion of Manti Canyon that may have some archaeological potential. No known sites have been found in the vicinity of the dam site(s).	This alternative would improve no adverse impact upon archaeological or historical resources.	Same as Alternative 4	No impact upon archaeological and historical remnants would be rendered by this alternative.	Same as Alternative 4
RECREATION	This alternative would eliminate a popular fishing area on Manti Creek – near the confluence of Cottonwood Creek and Manti Creek. Minor traffic congestion could be expected on Forest Service Road 50045 during construction.	This alternative would have no adverse or beneficial impacts upon recreation pursuits in Manti Canyon. Some minor traffic congestion could be expected on Forest Service roads during construction.	This alternative would have no effect upon recreational pursuits in Manti Canyon.	Alternative 6 would have no significant or lasting effects upon recreational activities in Manti Canyon.	Same as Alternative 6	No effect on recreation in Manti Canyon
COMMUNITY UTILITIES AND FACILITIES	The bypass pipeline would cross the City of Manti domestic water transmission line at least twice. Special precautions in design and construction would be required. Lower level maintenance in the irrigation network could be a beneficial effect of this alternative.	Forest Service Road 50045 would be relocated. Some temporary traffic congestion in the construction area would occur.	Alternative 4 would not induce any adverse effects upon community facilities either during construction or after the project had been completed. Less maintenance in the irrigation network could be accomplished by this alternative.	Alternative 6 would not induce any adverse effects upon community utilities or facilities.	Maintenance requirements in the irrigation network would be higher than those required under the "build" alternatives. Maintenance requirements would, however, diminish in successive years as the stream assumes preslide conditions.	No effect on the community utilities and facilities
SENORY ENVIRONMENT	The cumulative effects of this alternative could result in the greatest adverse visual impact.	The dam would be a prominent feature, yet would not diminish some of the important features in this portion of the canyon.	This alternative more than any other would improve the quality of the most devastated portion of the slide toe area. This visual improvement, however could be at the expense of degrading the visual appearance in the east and west ends of the slide toe.	The only significant visual impact of this alternative would be the death of the willow community. This would cause only very localized degradation of visual quality.	No visual change would occur.	No visual change would occur.

**TABLE IV-2
COMPARATIVE SUMMARY MATRIX**

ENGINEERING CONSIDERATIONS	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 4	ALTERNATIVE 6	ALTERNATIVE 7	ALTERNATIVE 9
DESCRIPTION	The bypass pipeline diverts flows less than 860 cfs 100-year flood around the landflow. The bypass consists of a concrete diversion structure, 66-inch diameter steel pipeline and flip bucket energy dissipater.	Debris dam at the mouth Manti Canyon. The dam consists of a 40-foot high earth embankment concrete emergency spillway and outlet works.	Stabilize Manti Creek at the toe of the landflow with large riprap.	Divert Cottonwood Creek around the mudflow and Conrad Reservoir. The diversion consist of two earth filled diversion structures with an earthenlined canal and 48-inch diameter pipeline.	Take no corrective action to mitigate the effects of the slide.	Add a liquid polymer flocculant to Manti Creek and utilize the existing debris basin as a settling basin. A small equipment and storage facility is required to store the polymer and add the flocculant to the stream.
IMPLEMENTATION	The inlet structure and energy dissipater would be constructed on Manti Creek. The pipeline would be located on the north side of the canyon.	Design of the debris dam would required a detailed geotechnical investigation to determine foundation conditions and borrow areas. Construction of the embankment would be constructed using conventional earthmoving equipment.	Stabilization of Manti Creek is the most difficult alternative to construct. Access to the Creek bottom is difficult. Placement of riprap would have to be accomplished with a dragline operating from the bank. A riprap source with sufficient large rock would have to be located.	Construction of the diversion structures, canal, and pipeline would require a minimal construction effort. Access to the site would require improvement of the existing jeep trail.	Not applicable	The equipment and storage facility would be located upstream of the existing debris basin. Construction of the facility would require the least construction effort of the alternatives.
COSTS						
Construction	\$1,249,000	\$774,000	\$2,005,000	\$91,300	\$ 0	\$31,790
Maintenance & Operation	\$ 2,600	\$ 59,200	\$ 13,000	\$15,400	\$16,000	\$88,350
Annual Equivalent Costs	\$ 98,700	\$118,800	\$ 167,200	\$22,400	\$16,000	\$91,200
RELIABILITY	The pipeline is located on the "Old North Slide". Although rapid movement is not expected, creep movement has been observed and is expected to continue. Depending on the amount of movements some modifications of the pipeline may be required.	The debris dam would require cleaning of sediment every 5 to 8 years. This maintenance could be accomplished using procedures previously employed.	The stabilization is considered least reliable because any further movement of the toe would disrupt the creek bed and displace much of the riprap.	The diversion structures, canal, and pipeline inlet works will require yearly cleaning. The diversion is not affected by the Cottonwood landflow.	Should high sediment levels continue cleaning of irrigation laterals and tilling of sediment deposits would be required.	The effective operation of the polymer treatment is dependent on a trained operator applying the proper dosages of the flocculants the debris basin would require annual cleaning of sediments.
LAND REQUIREMENTS	2.5 acres	4 acres	2 acres	1 acre	None	No additional land is required.
EFFECTIVENESS IN REDUCING SEDIMENT	Yarns Reservoir settles sediment in Cottonwood Creek. The toe is eliminated as a source of sediment. The sources of sediment are only those that existed before the landflow.	Affects all sediment in Manti Creek. However, not all of the silt and clay size sediment is settled out.	Eliminates the toe of the landflow as a source of sediment for flows less than the 100-year flood. Some erosion and displacement of riprap is expected for flows exceeding the 100-year flood. Does not affect sediment derived from the head of the landflow or other sources in the Canyon.	Eliminates the mudflow and Conrad Reservoir as sources of sediment. Does not affect sediment derived from the toe of the landflow or other sources in the Canyon.	Not applicable	Most effective of the alternatives. If properly operated, the polymer treatment is expected to eliminate most of the clay and silt size sediment in Manti Creek.

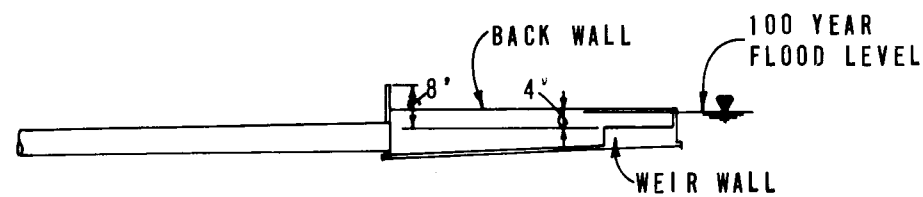




NOTE:
ALL SLOPES 3:1
UNLESS OTHERWISE
NOTED.

PLAN

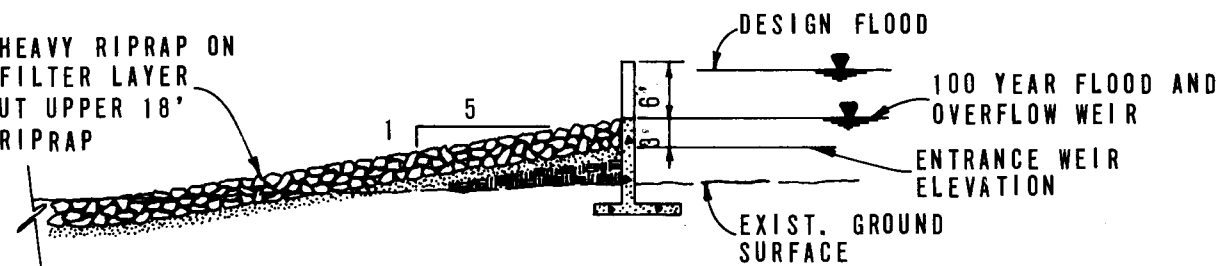
1"=40'



SECTION A

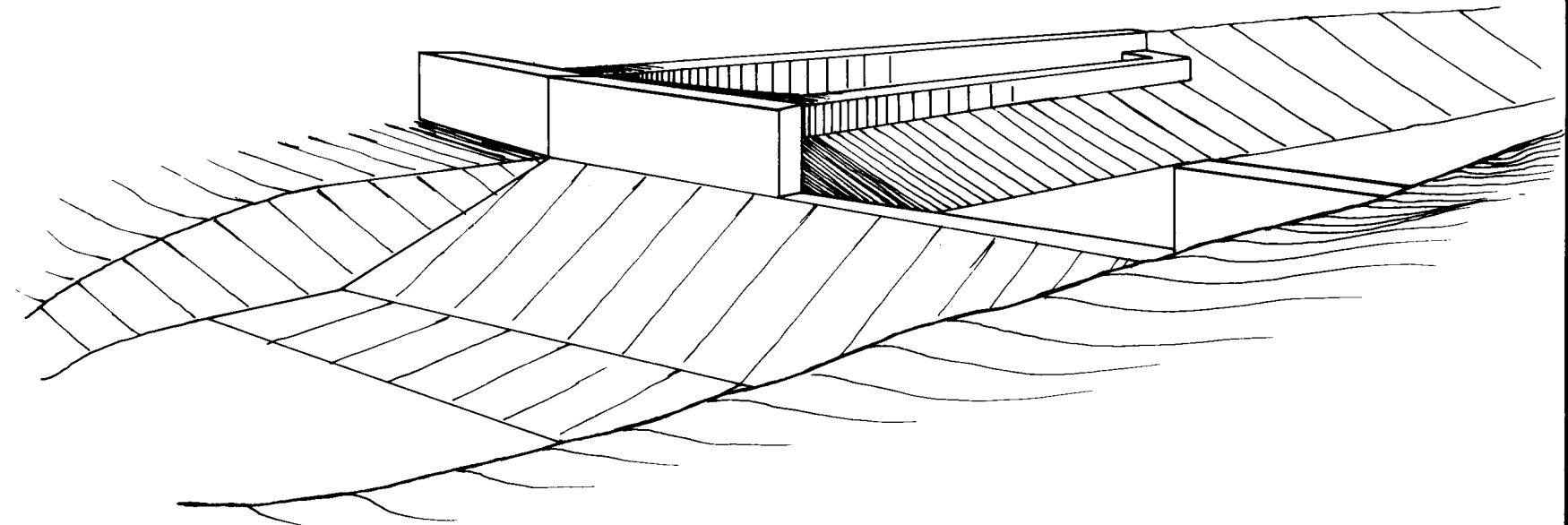
1"=40'

3" HEAVY RIPRAP ON
1' FILTER LAYER
GROUT UPPER 18'
OF RIPRAP

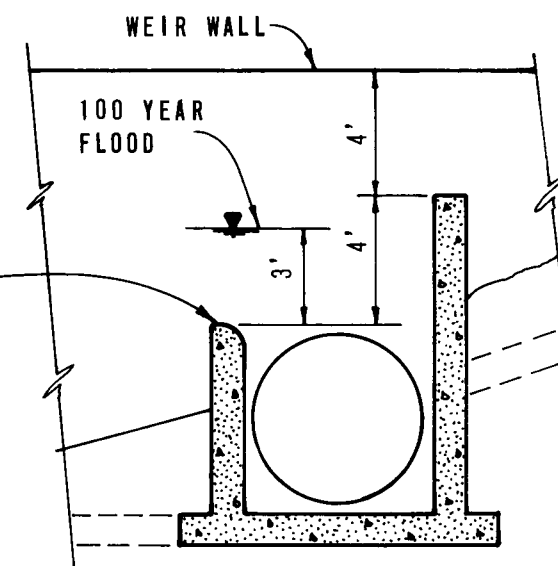


SECTION B

1"=20'

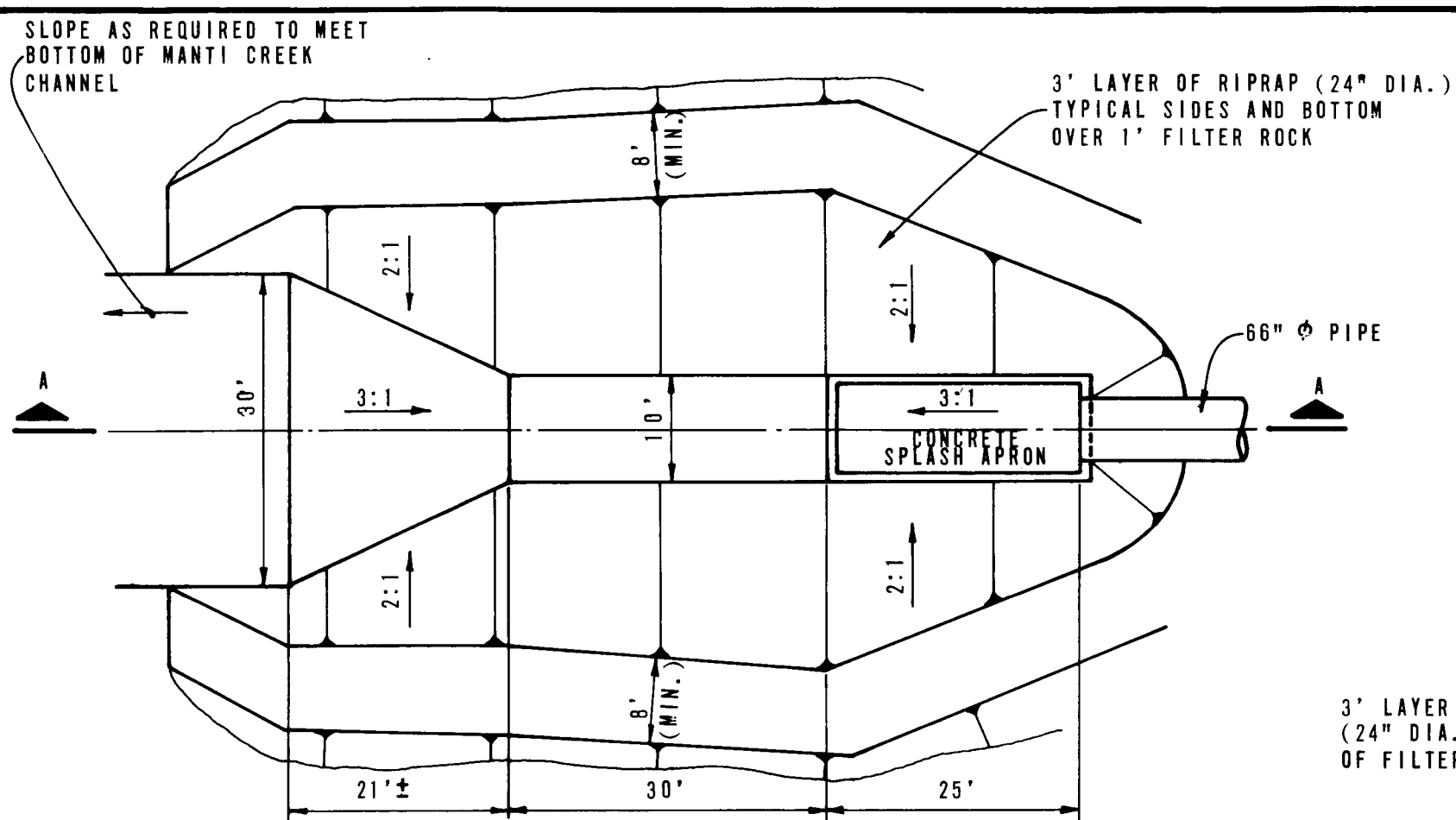


PERSPECTIVE



SECTION C

1"=6'



3' LAYER OF RIPRAP
(24" DIA.) OVER 1'
OF FILTER ROCK

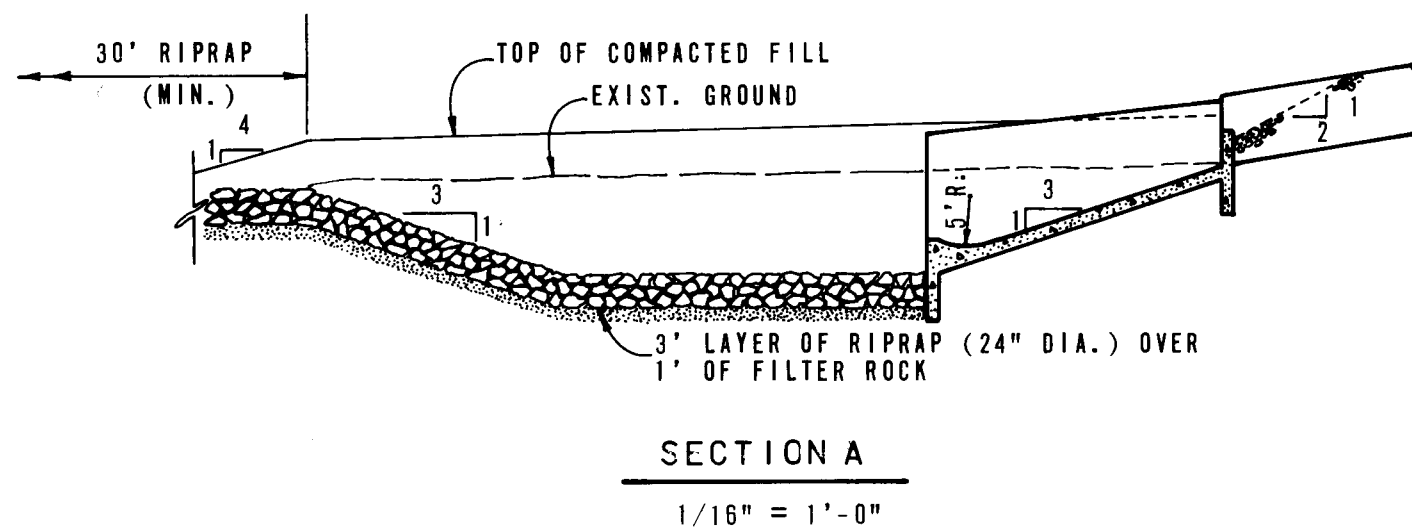
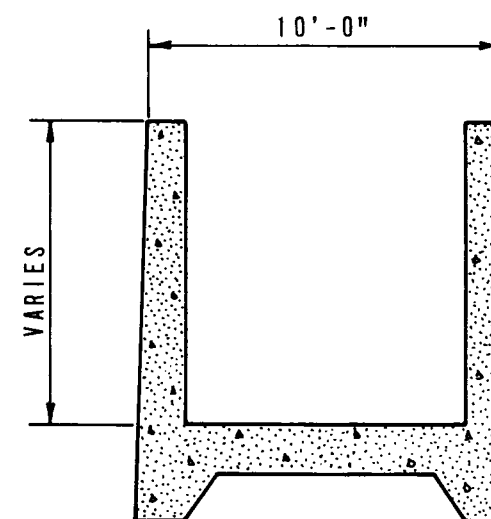
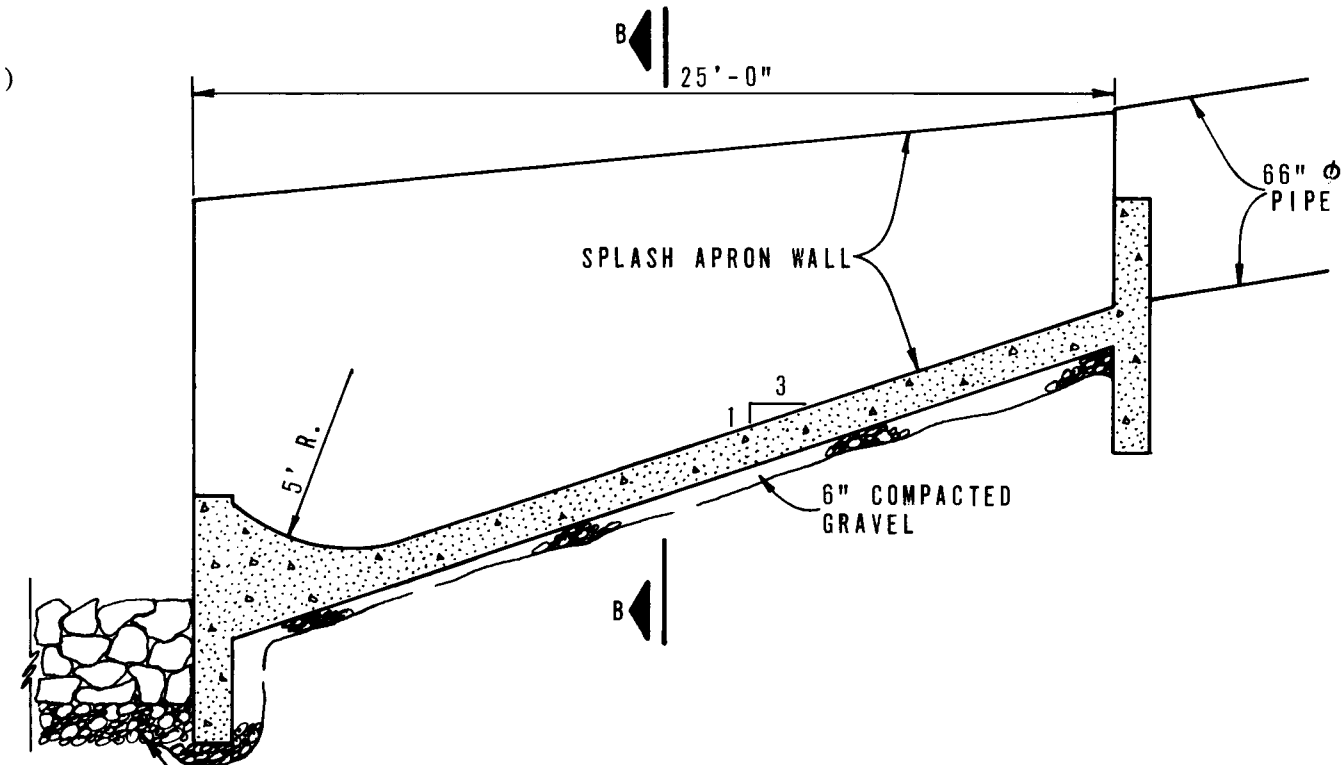
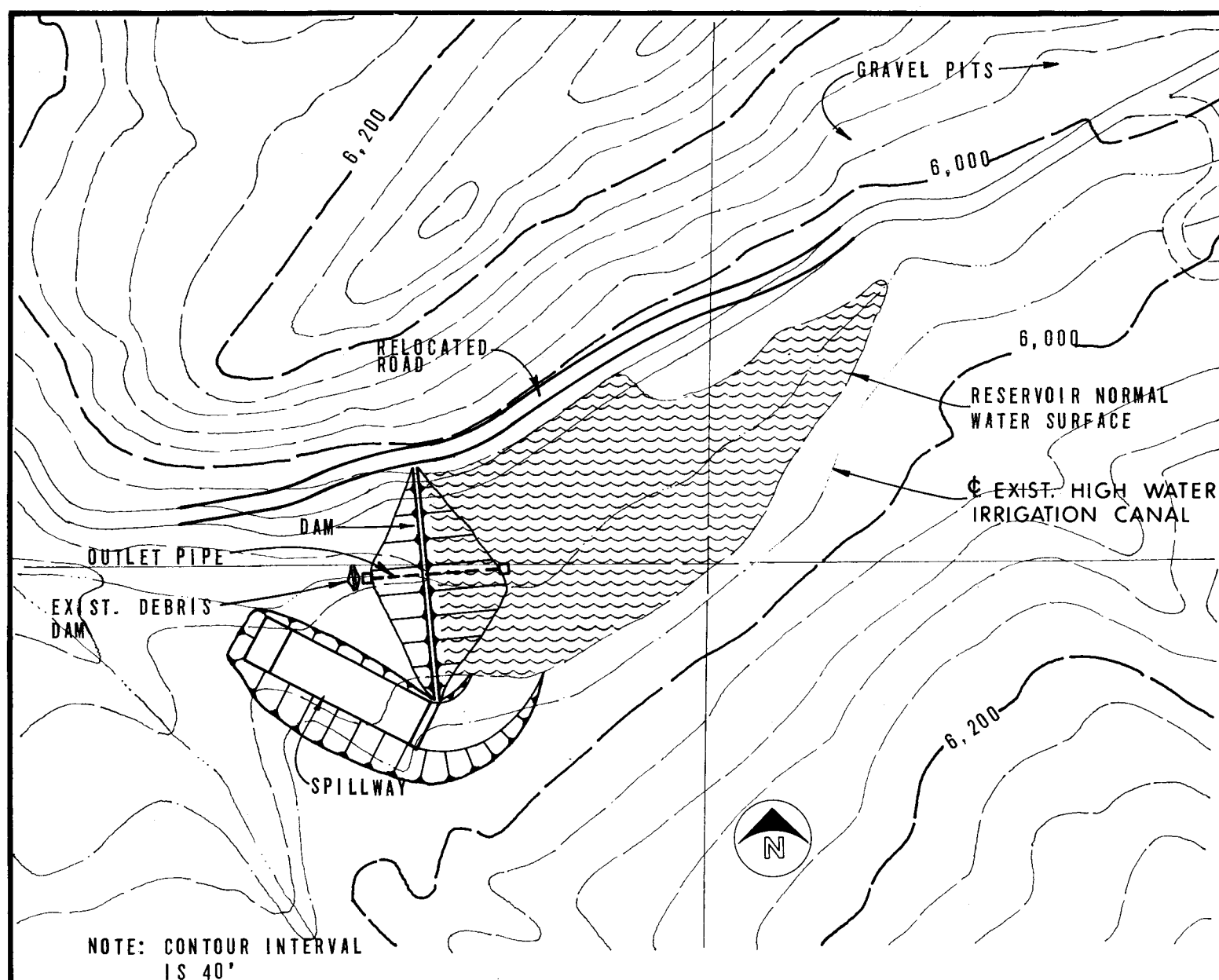


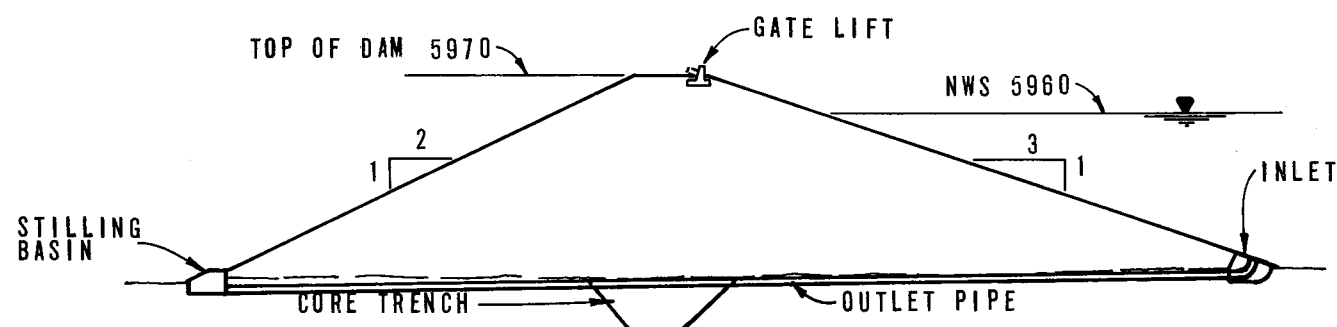
FIGURE IV-3
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
BYPASS PIPELINE, STILLING BASIN



NOTE: CONTOUR INTERVAL IS 40'

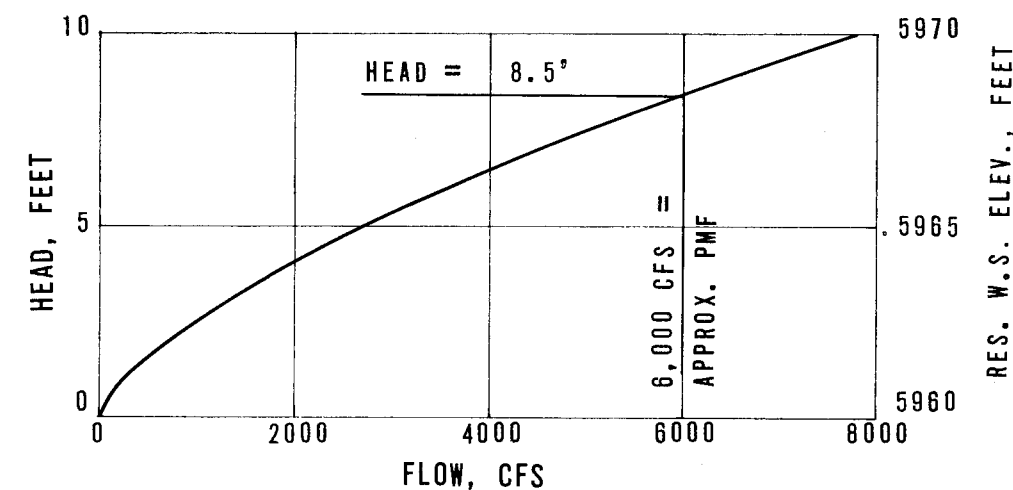
PLAN-DEBRIS DAM AND SPILLWAY

1"=300'

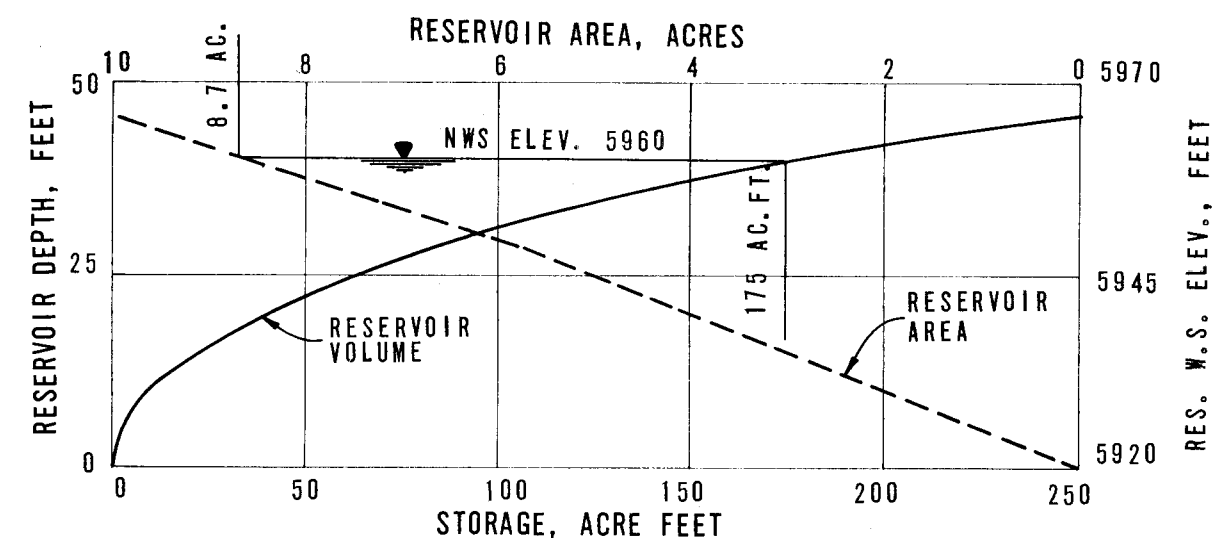


SECTION OF DAM THRU OUTLET

1"=50'

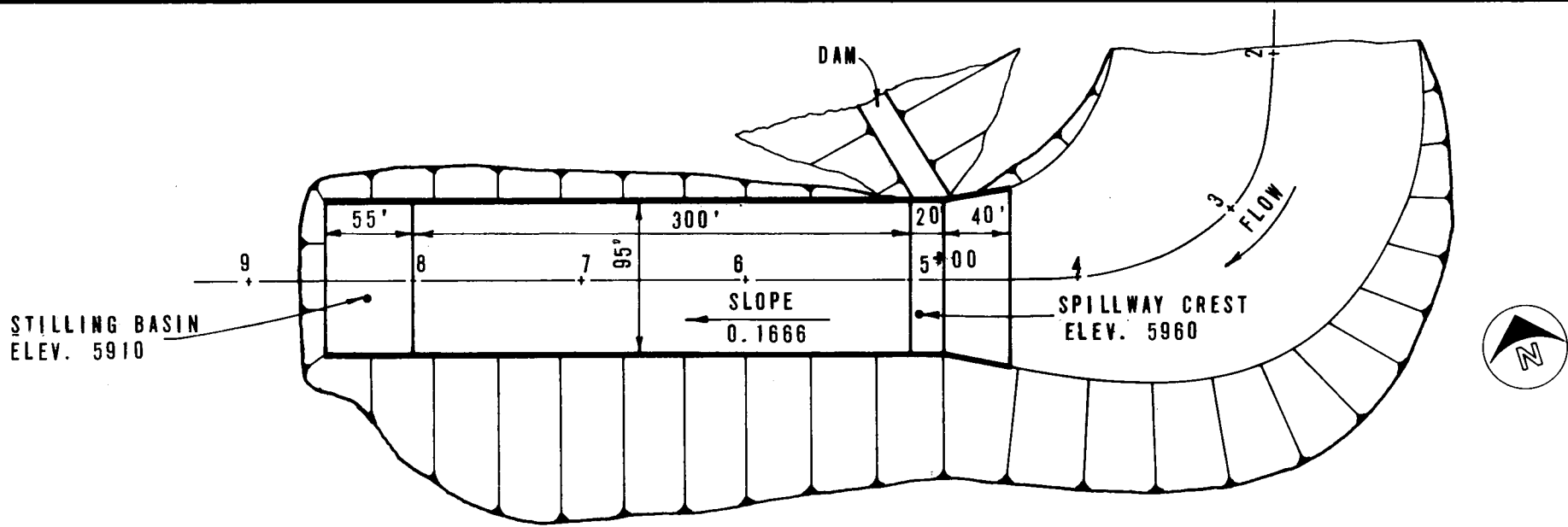


SPILLWAY RATING CURVE

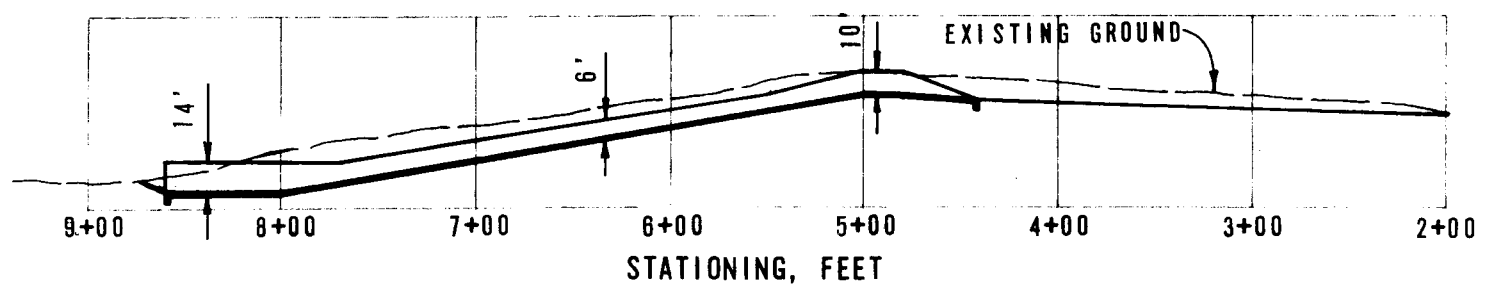


RESERVOIR STORAGE-AREA CURVES

FIGURE IV-4
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
DEBRIS DAM, SITE PLAN, SECTION
AND STORAGE-AREA CURVES



PLAN
1"=100'



PROFILE
1"= 100'

FIGURE IV-5
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
DEBRIS DAM SPILLWAY



NOTE: "A" & "B" INDICATE TYPE OF CHANNEL REQUIRED, SEE FIG. NO.

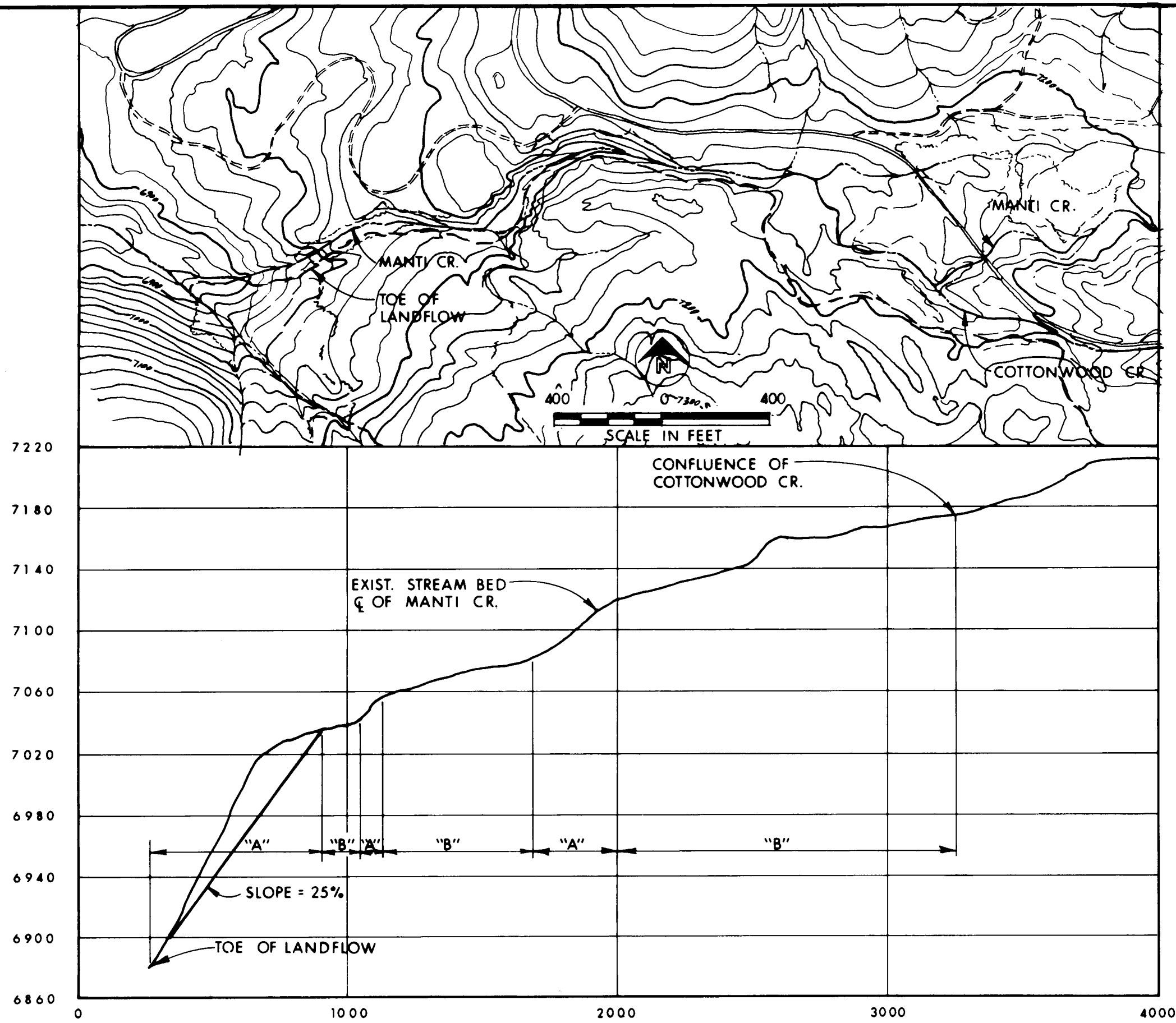
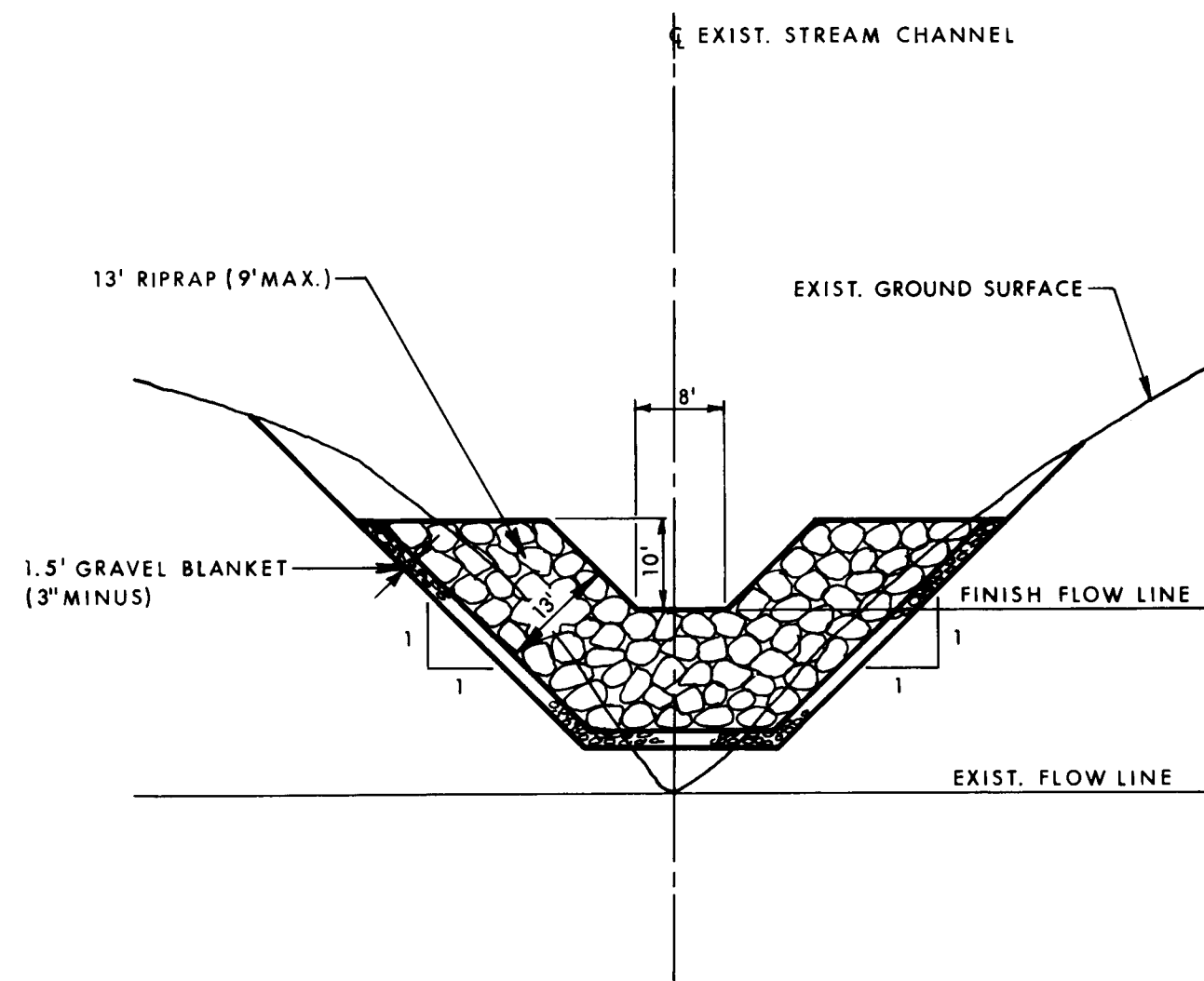
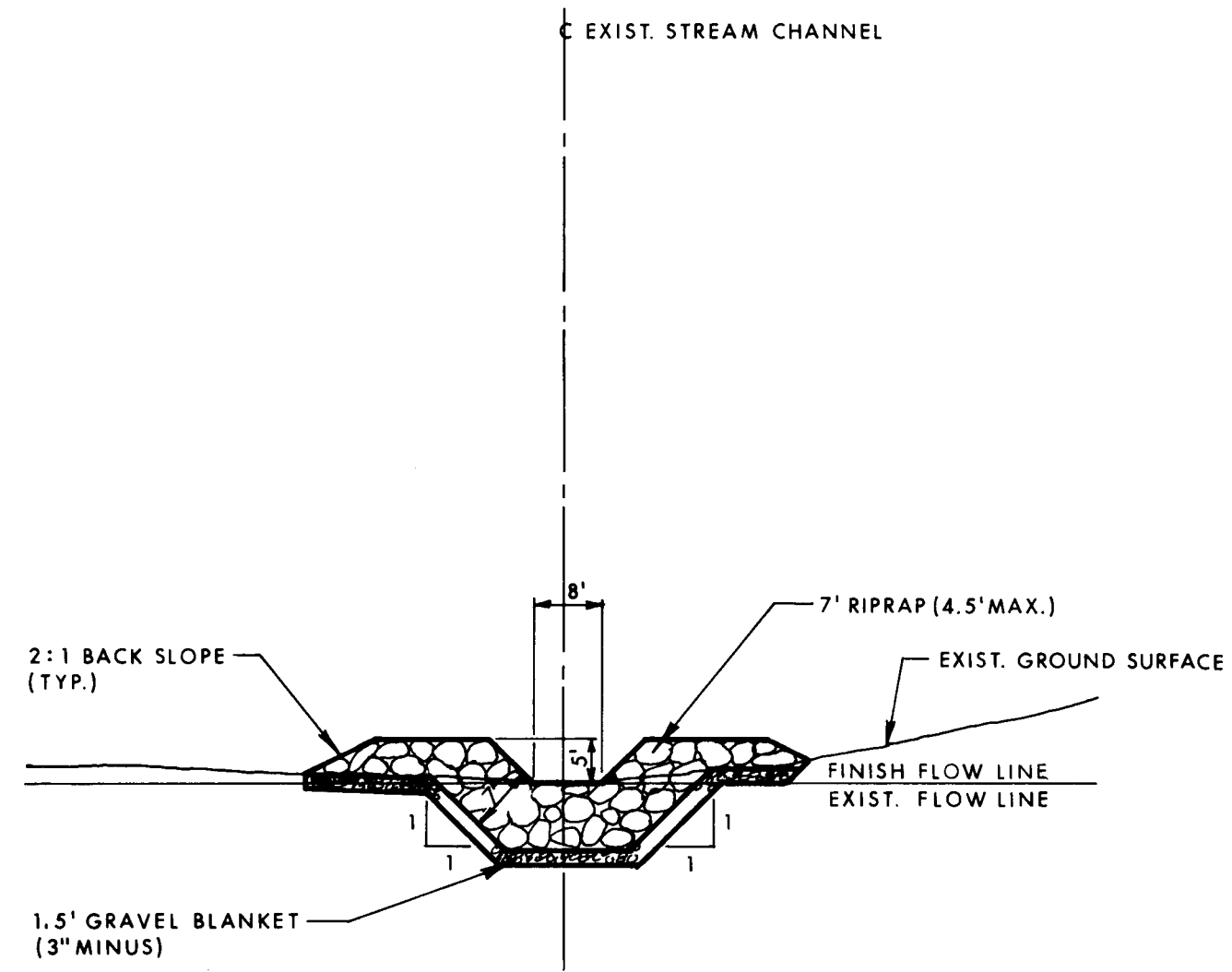


FIGURE IV-6
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
PROFILE OF MANTI
CREEK STABILIZATION





TYPICAL SECTION
FOR
SLOPES GREATER THAN 10%
(TYPE "A")



TYPICAL SECTION
FOR
LESS THAN 10%
(TYPE "B")

SCALE : 1" = 20'

FIGURE IV-7
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
STABILIZE MANTI CREEK
TYPICAL SECTIONS

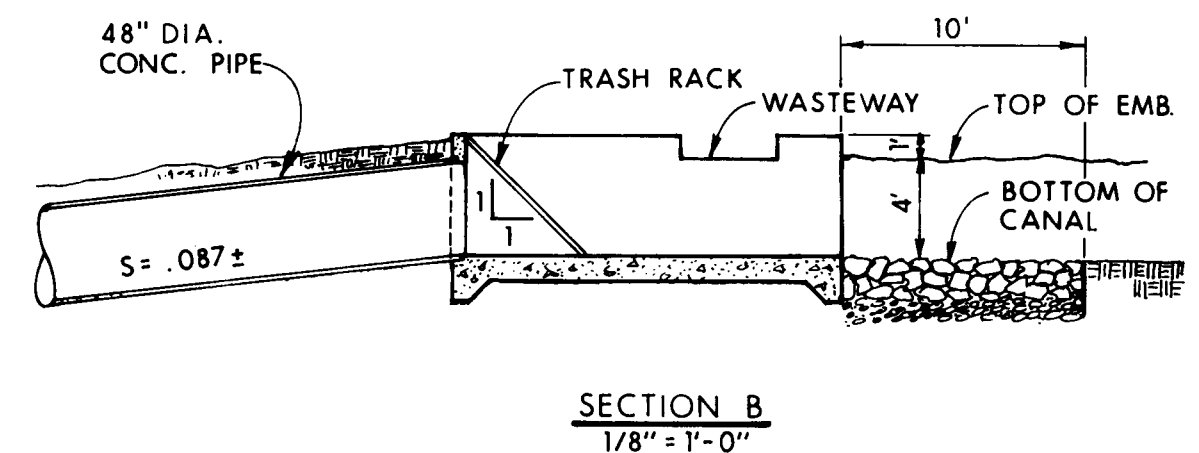
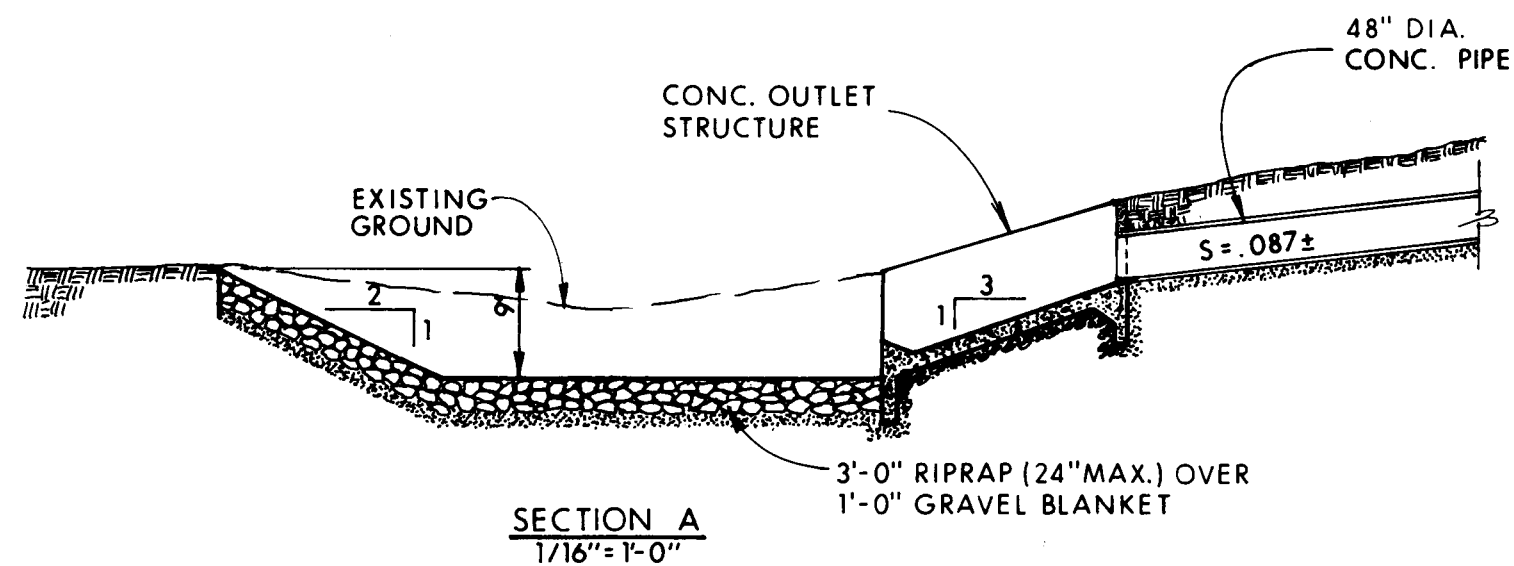
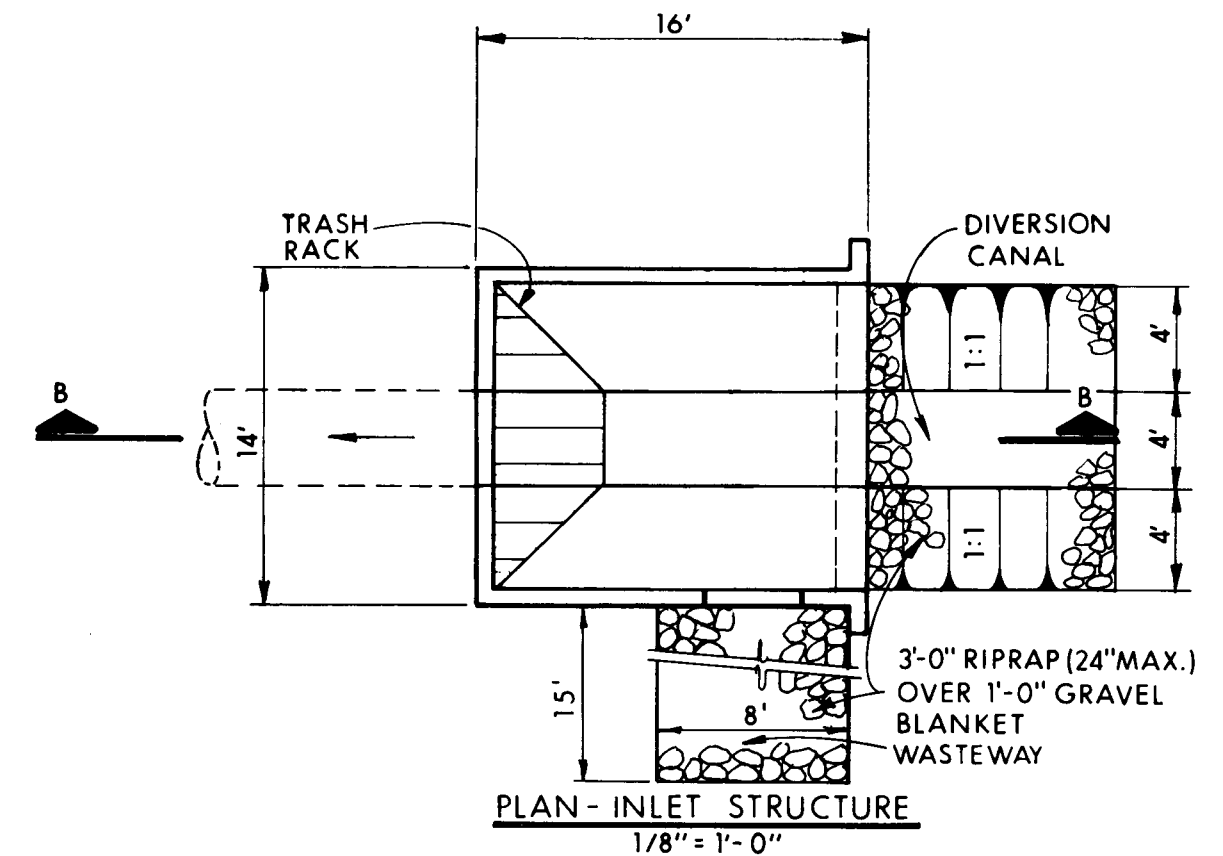
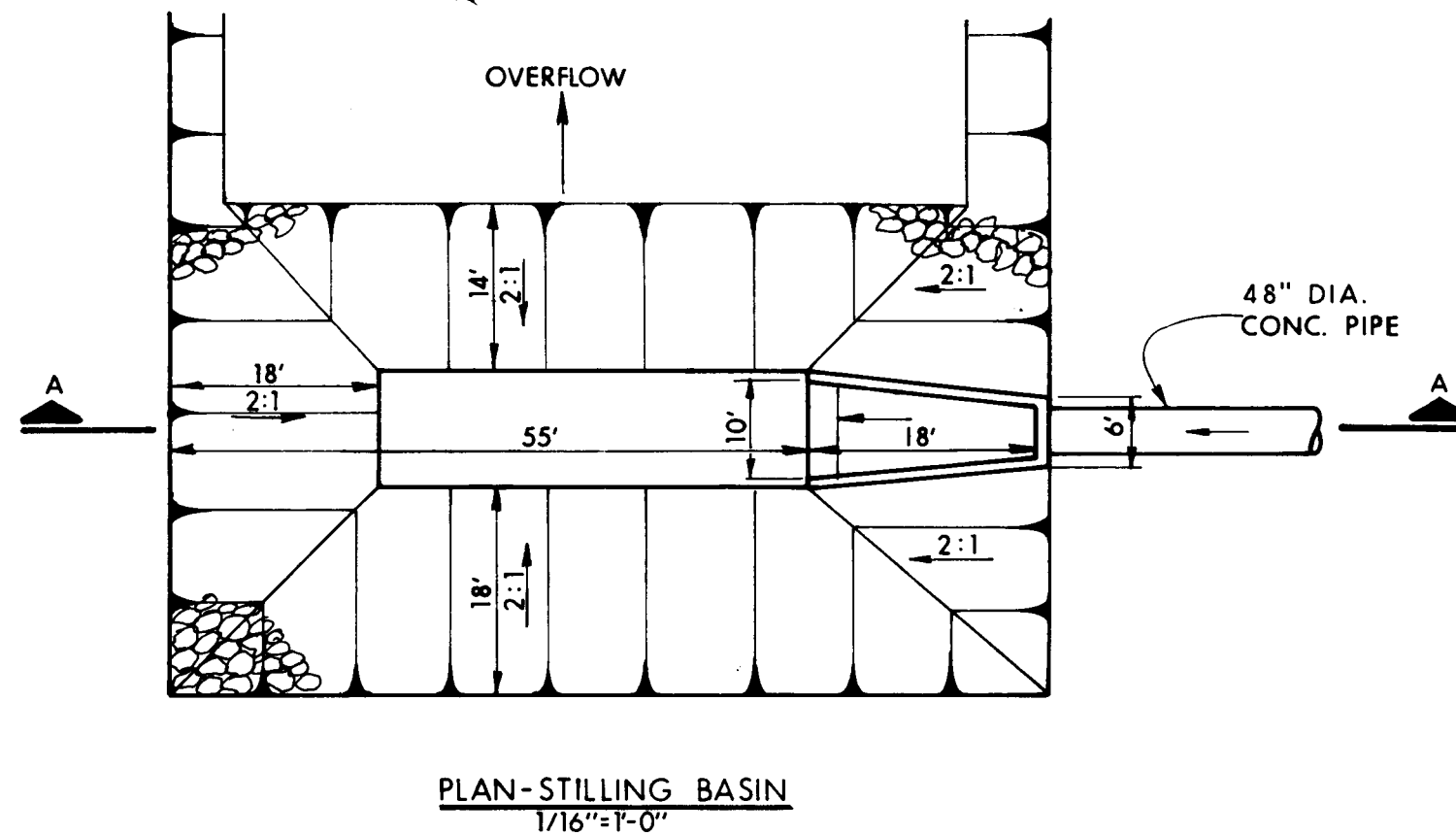
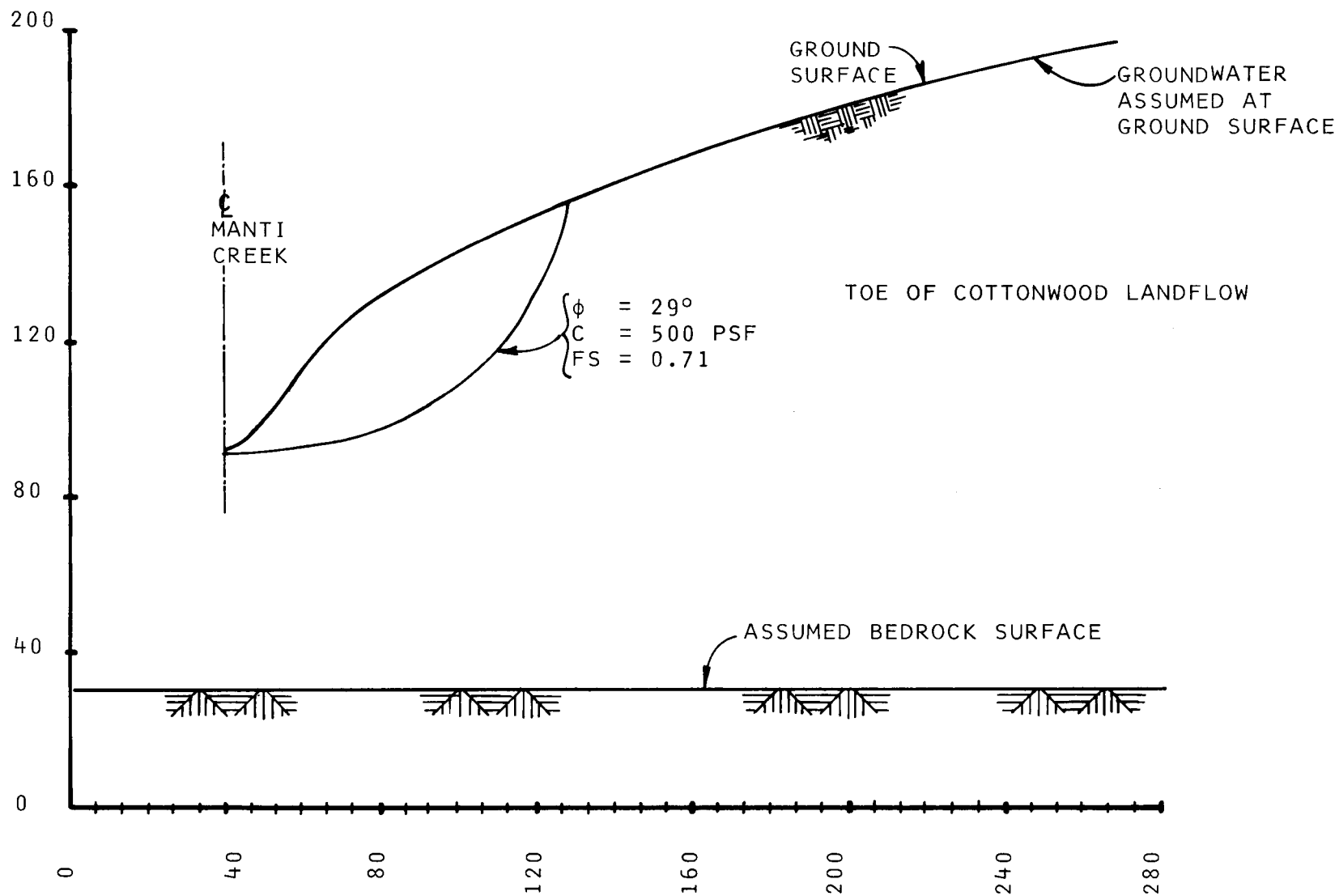


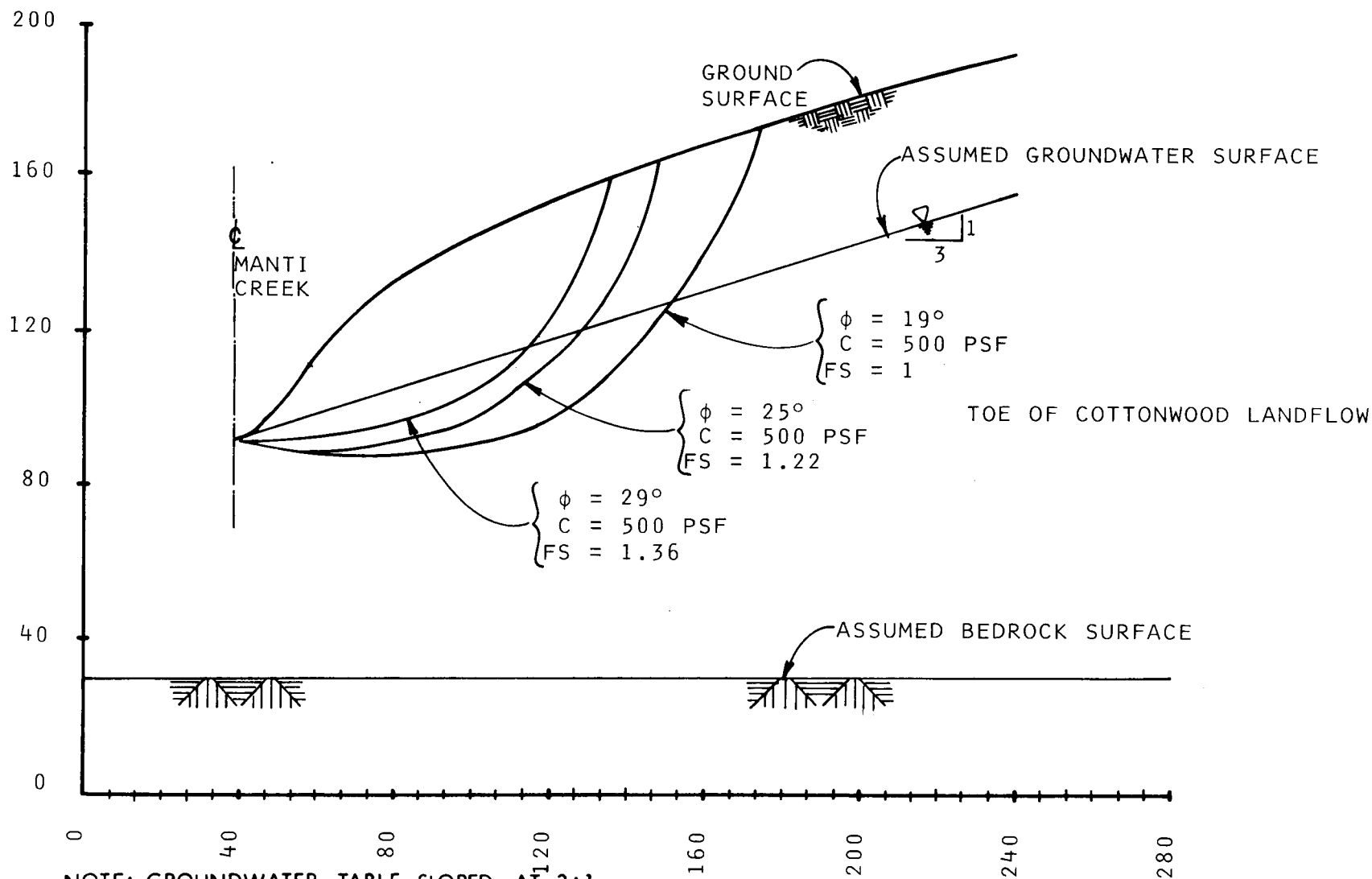
FIGURE IV-9
U.S. FOREST SERVICE
COTTONWOOD LANDFLOW
ALTERNATIVE EVALUATION
DIVERT COTTONWOOD CREEK
INLET AND OUTLET STRUCTURES



NOTE: GROUNDWATER TABLE AT GROUND SURFACE

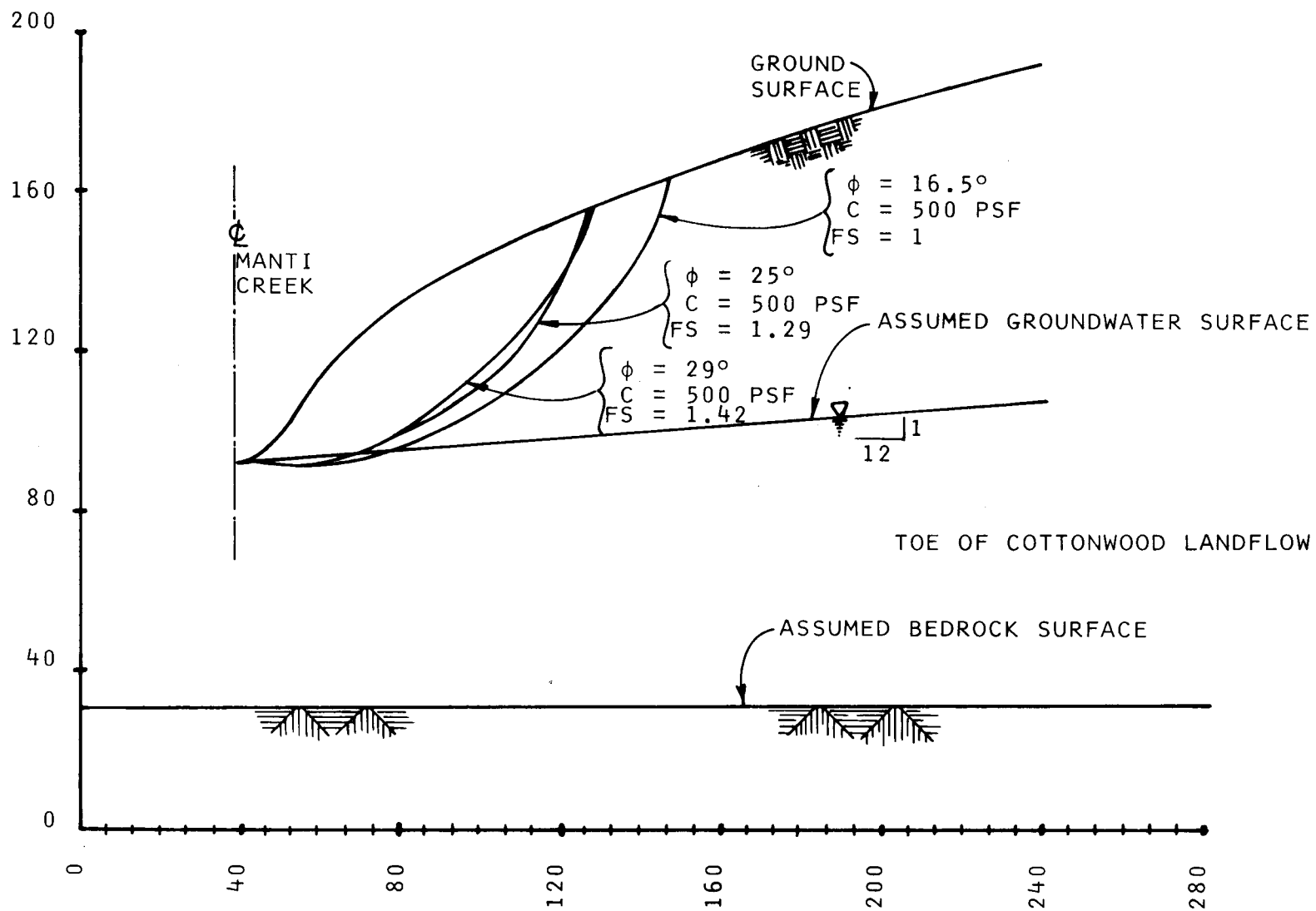
ϕ = ANGLE OF INTERNAL FRICTION
 C = COHESION - POUNDS PER SQUARE FOOT
 F.S. = FACTOR OF SAFETY

FIGURE IV-10
 U.S. FOREST SERVICE
 COTTONWOOD LANDFLOW
 ALTERNATIVE EVALUATION
STABILITY ANALYSIS RESULTS



ϕ = ANGLE OF INTERNAL FRICTION
 C = COHESION - POUNDS PER SQUARE FOOT
 $F.S.$ = FACTOR OF SAFETY

FIGURE IV-11
 U.S. FOREST SERVICE
 COTTONWOOD LANDFLOW
 ALTERNATIVE EVALUATION
 STABILITY ANALYSIS RESULTS



NOTE: GROUNDWATER TABLE SLOPED AT 12:1

ϕ = ANGLE OF INTERNAL FRICTION
 C = COHESION - POUNDS PER SQUARE FOOT
 F.S. = FACTOR OF SAFETY

FIGURE IV-12
 U.S. FOREST SERVICE
 COTTONWOOD LANDFLOW
 ALTERNATIVE EVALUATION
 STABILITY ANALYSIS RESULTS

Chapter 5

CONCLUSIONS & RECOMMENDATIONS



CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This examination of the Cottonwood landflow and study of possible remedial measures prompts the following conclusions:

- The possibility of the damming and flooding sequence is not considered a potential threat. The landflow could possibly cross Manti Creek forming a dam and impounding a reservoir of water which could, in turn, breach the landflow dam flooding the City of Manti. The probability of this event was determined to be very unlikely or could be easily mitigated if the landflow movement were to resume.
- Based on field observations and results of the U.S. Forest Service monitoring program, the Cottonwood landflow appears to be stabilizing. Although movement of the landflow is decreasing, it is never expected to completely stop. Creep type movement is expected. Heavy rains and/or snowmelt may reactivate the landflow, but movement should be of much smaller magnitude than that observed in 1974 and 1975.
- The landflow has contributed to periods of high stream sedimentation. The greatest concentrations of stream sediment were observed during Fall 1975 when the landflow was moving and in Spring 1976 after the landflow had slowed considerably.

- The effects of sediments on irrigated farmlands are considered relatively insignificant and not expected to reach significant levels.
- The limited amount of quantified historic reliable data does not permit an accurate assessment of the landflow's total contribution to stream sedimentation compared to contributions from other regions of the Canyon. Therefore, accurate predictions of stream sedimentation for future conditions based on the landflow as a source of sediments cannot be made.
- The geologic conditions in Manti Canyon are conducive to landslides. Landslides have occurred in the past and may occur in the future along nearly the entire length of the canyon. By taking corrective action on this landflow a precedent may be established requiring that action be taken on other landslides in the canyon.
- None of the alternative solutions examined would reduce the effects of natural flooding in the Manti Creek drainage basin. Natural flooding could still exceed the capacity of the City of Manti flood control channels.
- The construction of a bypass pipeline would reduce more of the sediments contributed from the landflow than the other options. The alternative, however, would have the greatest adverse impact upon the environment of any "build" alternative. Also, reliability is threatened by the instability of the north slide.

- Topographic and geologic conditions in Manti Canyon are not favorable for large dam and reservoir sites. These limiting conditions favor the construction of a debris dam less than 40 feet high. This impounded reservoir would not settle out the clay and small silt size particles during Spring runoff.
- The Cottonwood Creek bypass around Conrad Reservoir would have only minor impact upon the environment but would do little to decrease sediment levels in Manti Creek.
- The option to stabilize the toe of the Cottonwood landflow could substantially reduce stream sediments contributed by the slide toe. The option could cause moderate adverse impacts upon the environment, but also has some beneficial impacts which are significant. The reliability of the solution is dependent upon the stability of the landflow.
- Polymer treatment of Manti Creek would settle out most of the silt and clay material. An operator would have to be trained to apply the polymer in proper dosages. Annual maintenance and polymer costs are high. The alternative has little effect on the environment.

RECOMMENDATIONS

Based upon the preceding conclusions, no corrective actions to mitigate the effects of the Cottonwood landflow are recommended. This recommendation is based upon the following considerations:

- There are many other landslides in Manti Canyon. Any corrective action might be nullified by the reactivation of any one of the other landslides.
- The landflow already appears to be stabilizing and approaching pre-slide conditions.
- The possibility of the damming and flooding of Manti Creek caused by future movement of the landflow is considered very unlikely and is not considered a threat to the City of Manti.
- The effects of sediments on irrigated cropland appear to be relatively insignificant.
- The limited amount of quantified, reliable data does not permit an accurate assessment of the landflow's contribution to stream sedimentation; nor does it permit predictions of future stream sedimentation.

A subordinate recommendation is that a monitoring program be established. Streamflow, sediment concentrations and sediment sources in Manti and Cottonwood Creeks should be monitored to accurately determine and record the sediment transport cycle. Movement of the landflow should be monitored to determine movement patterns within the landflow, not just at the boundaries.

This monitoring program would serve to confirm or disprove the conclusions presented in this report -- that the Cottonwood landflow is stabilizing to pre-slide conditions, that sediment levels are decreasing, and that the effects

of the landflow are small. Should the monitoring program disprove these conclusions, the data gathered would provide a rational basis for the selection and design of corrective measures.

A monitoring program should be implemented to obtain information defining:

- Movement of the landflow
- Stream discharges in Manti Creek and Cottonwood Creek
- Sources and concentrations of sediments in Manti Creek and Cottonwood Creek
- Settling characteristics of the existing debris dam

Movement of the landflow could be monitored by aerial photography techniques. Aerial photography techniques have been found to be less time-consuming and more economical than conventional ground surveys. By placing targets throughout the landflow, movement occurring between photo dates can be detected quickly. In addition, qualitative data such as seepage, wet spots, and other signs of potential instability can be monitored. The purpose of such monitoring would be to verify the stabilization of the landflow. If movement continues, monitoring could determine the nature and rate of movement, and possibly determine the cause of such movement.

Streamflow measurements should be made on Manti Creek and Cottonwood Creek to determine the relationships between streamflow and sediment loads in Manti Creek and its tributaries. Streamflow measurements and sediment concentrations should

be measured using standard methods. Sampling should be performed monthly from August through March, weekly in April and July, and every two or three days in May and June.

Sediment loads should be measured at various places in Manti Canyon to determine sources and concentrations of sediment. In the upper landflow area, sampling stations should be located on the Burnt Hill Fork and Slide Fork of Cottonwood Creek and on Cottonwood Creek below Conrad Reservoir. In the lower landflow area, sampling stations should be located on Cottonwood Creek and Manti Creek above the slide and on Manti Creek below the toe of the landflow. Sampling stations should be located above and below the existing debris dam to determine the ability of the debris dam to remove suspended sediment.

The deposition of sediment in the farmlands should be monitored, using a program similar to that employed by Utah State University and the SCS, to determine the effects of sediment on crop production.

This monitoring program should be conducted for a sufficient period of time, approximately five years, such that annual relationships can be established and used to predict future conditions.

APPENDICES



APPENDIX A

LIST OF REFERENCES

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CORRESPONDENCE

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Letter from Lyman S. Willardson, Utah State University, to Clifford Miller, U.S. Forest Service, February 18, 1976.

Letter from Lorin Hunt, Soil Conservation Service, to Ned Madsen, Manti Irrigation District.

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PEOPLE CONTACTED

Allred, Charles: District Ranger, U.S. Forest Service

Allred, Gennis: Resident farmer of Manti

Allred, Glenn: Resident farmer of Manti

Anderson, Loren: Professor, Utah State University

Barton, Don: Resident farmer of Manti

Bridges, Bob: Hydrologist, Soil Conservation Service

Cox, Doug: Resident farmer of Manti

Cox, Merrill: Resident farmer of Manti

Dunsizer, Stan: American Cyanimid Company

Hansen, Eugene: Regional Materials Engineer, U.S. Forest
Service

Hunt, Lorin: Hydrologist, Soil Conservation Service

Johnson, Bob: Resident Farmer of Manti

Jones, Norell: Mechanic, Manti City Power

Kaliser, Bruce: Geologist, Utah Geological and Mineral Survey

Larsen, Ralph: Water Foreman, Manti City Power

Madsen, Ned: President, Manti Irrigation Company

McQuivey, Lee: Engineer, U.S. Army Corps of Engineer

Miller, Clifford: Director Engineering, U.S. Forest Service,
Region Four

Miller, Marvin: Resident farmer of Manti

Mortensen, Leland: Resident farmer of Manti

Olsen, Don: Councilman, City of Manti

Olson, Earl: Geologist, U.S. Forest Service

Peterson, Tony: Superintendent, Manti City Power

Smith, Gene: Graduate Student, Utah State University

Wanlass, Frank: Mayor, City of Manti

APPENDIX B

ANIMAL POPULATIONS IN THE MANTI LANDFLOW AREA

PINION-JUNIPER COMMUNITY (Below toe of landflow)

<u>Species trapped</u>	<u>Common name</u>	<u>Density</u>
<i>Peromyscus maniculatus</i>	Deer mouse	10 per acre
<i>Peromyscus truei</i>	Pinion mouse	4 per acre
<i>Eutamias umbrinus</i>	Uinta chipmunk	
<i>Eutamias dorsalis</i>	Cliff chipmunk	

Species observed

<i>Odocoileus hemionus</i>	Mule deer
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Species presence determined by scats or tracks

<i>Sylvilagus nuttallii</i>	Nuttall's cottontail
<i>Citellus variegatus</i>	Rock squirrel
<i>Neotoma cinerea</i>	Bushy-tailed woodrat
<i>Canis latrans</i>	Coyote

ASPEN COMMUNITY (Transition area)

<u>Species trapped</u>	<u>Common name</u>	<u>Density</u>
<i>Peromyscus maniculatus</i>	Deer mouse	4 per acre
<i>Glaucomys sabrinus</i>	Northern flying squirrel	4 per acre

Species observed

<i>Odocoileus hemionus</i>	Mule deer
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Species presence determined by scats or tracks

<i>Mustela frenata</i>	Longtail weasel
<i>Thomomys talpoides</i>	Northern pocket gopher
<i>Tamiasciurus hudsonicus</i>	Chickaree
<i>Sylvilagus nuttallii</i>	Nuttall's cottontail
<i>Taxidea taxus</i>	Badger

ASPEN-FIR COMMUNITY (With aspen, willow and sage segments)

<u>Species trapped</u>	<u>Common name</u>	<u>Density</u>
<u>Aspen-fir segment</u>		
<i>Peromyscus maniculatus</i>	Deer mouse	12 per acre
<i>Tamiasciurus hudsonicus</i>	Chickaree	

Willow segment

<i>Peromyscus maniculatus</i>	Deer mouse	5 per acre
<i>Reithrodontomys megalotis</i>	Western harvest mouse	
<i>Microtus montanus</i>	Montane vole	

Sage segment

<i>Peromyscus maniculatus</i>	Deer mouse	7 per acre
<i>Peromyscus boylii</i>	Brush mouse	3 per acre

Species observed any site of this area

<i>Mustela frenata</i>	Longtailed weasel
<i>Tamiasciurus hudsonicus</i>	Chickaree
<i>Thomomys talpoides</i>	Northern pocket gopher

Species presence determined by scats, tracks or structures

<i>Erethizon dorsatum</i>	Porcupine
<i>Odocoileus hemionus</i>	Mule deer
<i>Cervus canadensis</i>	Elk
<i>Castor canadensis</i>	Beaver

Other species expected but not trapped or observed

<i>Lupus townsendii</i>	White-tailed Jackrabbit
<i>Lepus californicus</i>	Black-tailed Jackrabbit
<i>Citellus armatus</i>	Uinta ground squirrel
<i>Taxidea taxus</i>	Badger
<i>Citellus variegatus</i>	Rock squirrel

Aspen-fir Community (Transition zone)

<i>Zapus princeps</i>	Western jumping mouse
<i>Sorex vagrans</i>	Wandering (Dusky) shrew
<i>Clethrionomys gapperi</i>	Red-backed mouse

Aspen-Fir Community

<i>Microtus richardsoni</i>	Water vole
<i>Lagurus curtatus</i>	Sagebrush vole

Zapus princeps
Sorex palustris
Sorex cinereus
Ochotona princeps
Marmota flaviventris

Western jumping mouse
Water shrew
Masked shrew
Pika
Yellow-bellied marmot

SPECIES EXPECTED AT ALL SITES BUT NOT TRAPPED, OBSERVED
OR DETERMINED BY OTHER EVIDENCE:

Canis latrans
Lynx rufus
Cervus canadensis
Erethizon dorsatum
Eutamias minimus
Urocyon cinereoargenteus
Mustela erminea
Spilogale gracilis
Myotis lucifugus
Myotis volan
Eptesicus fuscus
Corynorhinus townsendii

Coyote
Bobcat
Elk
Porcupine
Least chipmunk
Gray fox
Ermine
Western spotted skunk
Little brown bat
Long-legged bat
Big brown bat
Townsend's big-eared bat

Birds Observed

Turdus migratorius
Junco oreganus
Circus cyaneus
Accipiter cooperii
Cyanocitta stelleri
Gymnorhinus cyanocephalus
Pico pica
Colaptes cater
Dendrocopos villosus
Carpodacus cassinii
Myadestes townsendii
Bonasa umbellus

Robin
Oregon junco
Marsh hawk
Cooper's hawk
Steller's jay
Pinion jay
Magpie
Red shafted woodpecker
Hairy woodpecker
Cassin's finch
Townsend's solitaire
Ruffed grouse

APPENDIX C

COST ANALYSIS

Preliminary cost estimates for each alternative are summarized below. These cost estimates are based on information furnished by:

- Earthwork Contractors
- CH2M HILL Estimating Personnel

The estimated costs for each alternative include:

- Contractor's direct costs
- Contractor's overhead and profit
- Engineering and construction inspection
- Construction contingencies

These estimates do not include:

- Costs for purchasing right-of-way
- Legal and administrative costs

These estimates reflect cost levels of December 1976, with the Engineering News Record Cost Index at 2,500. The contingency allowance is included in the cost estimates to cover uncertainties associated with preliminary design and assumed methods of construction. Also included in the contingency are such factors as availability of materials and equipment, number of contractors available to bid the work, limiting construction schedule, etc. A contingency allowance of 30 percent is applied to all alternatives.

It should be recognized that many assumptions based on experience, judgment and available information must be made in a preliminary cost estimate. These assumptions must be examined closely and verified prior to final selection of an alternative. Critical assumptions are noted under each alternative.

The annual equivalent cost of all alternatives was computed to compare each alternative on an equal basis. The estimates were based on the following assumptions:

- 20-year amortization at 6-3/8 percent interest
- land cost - not included
- structure life - 40 years
- annual maintenance costs includes an allotment for cleaning irrigation systems

TABLE C-1
EQUIVALENT ANNUAL COST

Description	1	2	Alternative			7	9
			4	6	6		
First Cost	\$1,249,000	\$774,000	\$2,005,000	\$ 91,300	\$ 0	\$ 31,790	
Salvage at retirement - straight life basis (based on 40-year life, 20-year amort. period)	624,500	387,000	1,002,500	45,650	0	0	
Annual equivalent first cost	112,400	69,700	180,400	8,200	0	2,860	
Annual equivalent salvage cost	-16,300	-10,100	-26,200	-1,200	0	0	
Annual equivalent operation and maintenance project facilities	1,000	48,000	5,000	1,000	0	86,750	
Annual equivalent operation and maintenance irrigation systems	1,600	11,200	8,000	14,400	16,000	1,600	
Annual equivalent cost	\$ 98,700	\$118,800	\$ 167,200	\$ 22,400	\$16,000	\$ 91,200	

Alternative 1 - By-Pass Pipeline

<u>Item</u>	<u>Quan.</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Cost</u>
<u>Intake - Diversion</u>				
<u>Structure</u>				
Mobilization	-	L.S.	5%	\$41,200
Excavation	4,267	c.y.	\$ 1.50	6,400
Granular Bedding	472	c.y.	8.50	4,012
Riprap	1,417	c.y.	17.00	24,089
Concrete				
a. flat work	100.8	c.y.	86.00	8,669
b. walls	110.0	c.y.	265.00	29,150
c. grout for riprap	112.5	c.y.	79.00	<u>8,888</u>
			Subtotal	\$122,408
<u>Pipeline</u>				
Trench excavation	19,600	c.y.	1.85	36,267
Pipe bedding	5,010	c.y.	3.25	16,283
66" steel pipe, coated, in-place	5,280	l.f.	118.00	623,040
Backfill & grading	6,966	c.y.	2.80	19,505
Air release valves, complete	2	ea.	1200.00	2,400
Cross-drainage structures	5	ea.	4900.00	<u>24,500</u>
			Subtotal	\$721,995
<u>Energy Dissipator</u>				
Excavation	1643	c.y.	1.50	2,465
Granular bedding	170	c.y.	8.50	1,445
Riprap	511	c.y.	17.00	8,687
Concrete				
a. flatwork	11.1	c.y.	86.00	955
b. walls	24.6	c.y.	265.00	<u>6,519</u>
			Subtotal	\$ 20,071

Base estimated costs in-	
cluding overhead & profit	\$ 864,474
Contingency at 30%	<u>259,342</u>
	\$1,123,816
Insurance & bonds @ 1%	<u>11,238</u>
Estimated construction cost	\$1,135,054

Engineering & Construction	
Inspection @ 10%	<u>\$ 113,505</u>

■ TOTAL ESTIMATED PROJECT	
COST	<u><u>\$1,249,000</u></u>

■ ANNUAL MAINTENANCE COSTS	\$ 2,600
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Alternative 2 - Debris Dam on Manti Creek

<u>Item</u>	<u>Quan.</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Cost</u>
Mobilization	-	L.S.	5%	\$ 24,620
Stripping	5,300	c.y.	\$ 1.20	6,360
Core trench				
excavation	10,625	c.y.	2.00	21,250
Spillway excavation	33,100	c.y.	1.20	39,720
Dam fill	53,125	c.y.	1.50	79,688
Riprap bedding	1,867	c.y.	8.50	15,870
Riprap	2,800	c.y.	17.00	47,600
Granular drains	1,500	c.y.	8.50	12,750
Spillway concrete				
a. flat work	1,420	c.y.	86.00	122,120
b. walls	255	c.y.	265.00	67,575
Spillway drains	-	L.S.	-	6,000
Outlet pipe	270	l.f.	95.00	25,650
Intake, outlet works	25	c.y.	225.00	5,625
Stilling basin, outlet	30	c.y.	225.00	6,750
Slide gate, outlet	1	ea.	5,400	5,400
Road relocation	-	L.S.	-	20,000
Canal relocation	-	L.S.	-	<u>10,000</u>

Base estimated costs

including overhead & profit \$516,978

Contingency @ 30% 155,093

\$672,071

Insurance & bonds @ 1% 6,721

Estimated construction cost \$678,792

Engineering & construction

 inspection 95,000

■ TOTAL ESTIMATED PROJECT COST \$774,000

■ ANNUAL MAINTENANCE COST \$ 59,200

Alternative 4 - Stabilize Manti Creek

<u>Item</u>	<u>Quan.</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Cost</u>
Mobilization	-	L.S.	5%	\$ 66,000
Blasting*	150,000	c.y.	\$1.80	270,000
Large riprap*	29,000	c.y.	12.00	348,000
Smaller riprap*	46,000	c.y.	9.00	414,000
Gravel blanket	15,000	c.y.	4.40	66,000
Earthwork	45,000	c.y.	1.20	54,000
Dewatering	-	L.S.	20,000	20,000
Road pioneering*	-	L.S.	50,000	50,000
General Contractor				
Personnel	-	L.S.	60,000	60,000
Miscellaneous Equipment	-	L.S.	40,000	<u>40,000</u>

Base estimated costs in-	
including overhead & profit	\$1,388,000
Contingency @ 30%	<u>416,400</u>
Insurance & bonds @ 1%	<u>18,044</u>
Estimated construction cost	\$1,822,444
Engineering & construction	
inspection @ 10%	<u>182,244</u>

■ TOTAL ESTIMATED PROJECT COST \$2,005,000

■ ANNUAL MAINTENANCE COST** \$ 13,000

* Assumes a suitable site for blasting riprap can be found within 10 miles of the construction area. Also assumes blasting site can be made accessible with only road pioneering required -- no major blasting or bridge structures required.

** The estimated annual maintenance cost will cover basic construction equipment and labor required for general earthwork for 1 week per year.

Alternative 6 - Divert Cottonwood Creek

<u>Item</u>	<u>Quan.</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Cost</u>
Mobilization	-	L.S.	8%	\$ 4,200
Road work	-	L.S.	\$9,000	9,000
Diversion Canal				
Clearing & Grubbing	-	L.S.	2,000	2,000
Excavation	700	c.y.	1.50	1,050
Earth fill	1,630	c.y.	3.50	5,705
Gravel blanket	167	c.y.	4.40	735
Riprap*	445	c.y.	9.00	4,005
Mulching & Seeding	2,310	s.y.	1.00	2,310
Inlet Structure				
Excavation	50	c.y.	1.50	75
Compacted gravel	12	c.y.	4.00	48
Concrete	27	c.y.	200.00	5,400
Trash rack	1	L.S.	400.00	400
4' dia. Concrete Pipe, Excavation & Backfill	230	l.f.	50.00	11,500
Energy Dissipator - Outlet Structure				
Excavation	1,300	c.y.	1.50	1,950
Gravel blanket	360	c.y.	4.40	1,584
Riprap*	725	c.y.	9.00	6,525
Concrete	20	c.y.	200.00	<u>4,000</u>
Base estimated cost including overhead & profit				\$60,487
Contingency @ 30%				<u>18,146</u>
				\$78,633
Insurance & Bonds @ 1%				<u>786</u>
Estimated construction cost				\$79,419
Engineering & construction inspection @ 15%				<u>11,913</u>

■	TOTAL ESTIMATED PROJECT COST	<u>\$91,300</u>
■	ANNUAL MAINTENANCE COST	\$15,400

* Assumes the riprap can be blasted within a 10 mile radius and is easily accessible.

Alternative 7 - Do Nothing

- No immediate cost
- Maintenance was assumed to be similar to work completed in Spring of 1976. Movements of the landflow had stopped, and the only sediment deposited on the farmland was that which was carried by the spring flows.
- Equipment and personnel
 - 2 backhoes
 - 2 dump trucks
 - 2 operators
 - 5 laborers

■	ANNUAL MAINTENANCE COST*	\$ 16,000
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* Assuming equipment and personnel would be working for one month each year during periods of peak sediment load.

Alternative 9 - Polymer Treatment

<u>Item</u>	<u>Quan.</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Cost</u>
Mobilization			1%	\$ 2,000
Equipment and Storage Facility		L.S.		<u>20,000</u>
Base estimated cost including overhead and profit				\$22,000
Contingency @ 30%				<u>6,600</u>
				\$28,600
Insurance & Bonds @ 1%				<u>300</u>
Estimated construction cost				\$28,900
Engineering & construction inspection @ 15%				<u>\$ 2,890</u>
■ TOTAL ESTIMATED PROJECT COST				<u>\$31,790</u>
■ ANNUAL MAINTENANCE COST*				\$88,350
*Annual Maintenance Cost				
. sediment removal @ \$2/cubic yard				\$48,000
. polymer:				
assuming 5 mg/liter dosage				
\$1350/day x 25 days				\$33,750
. operators 25 days @ \$200/day				5,000
. cleaning irrigation systems				<u>1,600</u>
				\$88,350